Current and Forward Looking Experimental Approaches in Gluten-Free Bread Making Research

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Abstract[1]

Research efforts on gluten-free bread making have rapidly increased during the last decade. A lot of different approaches are being used to improve the quality of these products. The techniques used in gluten-free bread making research vary widely. This review focuses on the methodological aspects of gluten-free bread making research and extracts relevant data from all Web of Science peer reviewed research articles on gluten-free bread published from 2010 to date. Recipes and methodologies are grouped by (main) starch source and list other ingredients, additives and treatments used. The focus lies on the experimental setups typically used to analyze batter/dough and end product. Small deformation rheological measurements are typically performed on gluten-free batter/dough, along with several other batter/dough properties, but there is no clear link between these characteristics and the bread quality which typically is determined by volume and texture analysis or sensory evaluation. Some more recent techniques that have already been used on wheat bread or other bakery products are discussed as well. Their application in gluten-free bread making research may help extend the current knowledge.

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[1] Abbreviations: ^{1}H-NMR, proton nuclear magnetic resonance; 2D, two-dimensional; ADA, acetylated distarch adipate; CLSM, confocal laser scanning microscopy; (C)MC, (carboxy)methylcellulose; DAG, diacylglycerol; DATEM, diacetyl tartaric acid ester of mono- and diglycerides; DSC, differential scanning calorimetry; ERO, electrical resistance oven; EWP, egg white powder; FOS, fructooligosaccharides; GI, glycemic index; HACS, high amylose corn starch; HDP, hydroxypropyl distarch phosphate; HPMC, hydroxypropyl methylcellulose; IR, infrared; LAB, lactic acid bacteria; LBG, locust bean gum; MAG, monoacylglycerol; ML, Mixolab; MRI, magnetic resonance imaging; RVA, rapid visco analyzer; SEM, scanning electron microscopy; SPI, soy protein isolate; SSL, sodium stearoyl lactylate; TD, time domain; TGA, thermogravimetric analysis; TGase, transglutaminase; TPA, texture profile analysis; WP, whey protein

1. Introduction

Gluten proteins are the main storage proteins in wheat, and are responsible for the visco-elastic properties of wheat flour dough. People who suffer from coeliac disease, an intestinal intolerance to the storage proteins of wheat (i.e. all *Triticum* species), rye and barley (and sometimes oats), need to exclude these from their diet. While consumption of pure oats is safe for most coeliac patients, it is considered a gluten containing cereal in many countries because it is often contaminated with gluten containing cereals. Not only coeliac disease patients, but also people who suffer from non-coeliac gluten sensitivity and an increasing share of consumers who avoid gluten for lifestyle reasons follow a gluten-free diet. Whether or not linked to coeliac disease or other gluten-related disorders, gluten-free diets attract a lot of attention in the media nowadays. The market of gluten-free products grows and enormous efforts are underway to enhance their quality. Literature has described the lack of cohesiveness and elasticity of gluten-free batters/doughs. They are more difficult to handle than wheat flour dough and have poor gas holding capacity. The end products have a low volume, a crumbly texture, pale color, poor flavor and firm rapidly.

2. Peer-reviewed literature on gluten-free bread making is limited

The use of gluten-free ingredients such as alternative flours, starches, hydrocolloids, proteins, enzymes, lipids, pseudocereals, and sourdough have been extensively reviewed (Alvarez-Jubete et al., 2010; Anton and Artfield, 2008; Arendt et al., 2007; Capriles and Arêas, 2011, 2014; Comino et al., 2013; Deora et al., 2014; Falade and Akingbala, 2011; Gallagher et al., 2004; Gobbetti et al., 2007; Houben et al., 2012; Huttner and Arendt, 2010; Kulamarva et al., 2009; Matos and Rosell, 2015; O'Shea et al., 2014; Ohimain, 2015; Omary et al., 2012; Rahaie et al., 2014; Wolter et al., 2014d; Zannini et al., 2012).

A literature search on the topic “gluten-free bread” in Web of Science in April 2015 resulted in a list of 655 articles. A critical examination of the titles and abstracts was done to exclude all papers on gluten detection, quantification and detoxification and those only describing experiments on wheat products. Figure 1 shows the distribution in time of the 399 remaining articles concerning gluten-free bread with an estimate of the number of publications in 2015 (shown in grey) based on the number of publications during its first quarter. Since 2007 more than ten research articles are published every year. A stepwise increase is seen with approximately 30 articles published in 2008 and 2009 and approximately 50 each year from 2010 to 2013. In 2014 a steep increase is seen with 70 articles published that year. This steep increase seems to continue in 2015 (based on the estimate). Capriles and Arêas (2014) noticed a similar trend after performing a literature search on “gluten-free bread” up to the end of 2013. They found a slightly smaller amount of articles on gluten-free bread, probably due to the use of stricter search criteria.

A literature search on the topic “wheat bread” performed on the same day gave approximately 4800 articles of which more than 65 % were published before 2010 while for “gluten-free bread” only 28 % of the total number of publications were from before that date. A steep increase is seen in the number of articles on wheat bread from 2006 (approximately 160) to 2008 (approximately 300). Since 2008 the number of publications per year on wheat bread is rather constant.

Considering that all research papers on wheat bread deal only with one starting material, while in the research papers on gluten-free bread over different 20 origins of flours and starches are described, the number of papers on gluten-free bread from one flour or starch source is even more limited. Furthermore, as for wheat bread, there is wide variety of bread types based on regional habits, ranging from French-style bread, Brazilian cheese bread, Middle Eastern flat bread, Indian chapatti bread to West-European and North-American sliced bread.

3. Methodological aspects of gluten-free bread making research

This review takes a closer look at the literature on gluten-free bread making from 2010 up to the first part of 2015, thereby covering over 70 % of all Web of Science papers on gluten-free bread making. The focus lies on the different analytical techniques used to determine the quality of gluten-free batter/dough and bread. The 399 articles included in Figure 1 were narrowed down to only those describing original research on the West-European and North-American bread types. Such bread is typically sliced before use. 132 articles remained which are incorporated in the tables below. Each table groups the publications on a particular starch source, respectively rice flour, pure starches, 'alternative flours' and a combination of different flours and starches. Table 5 lists the research on sourdough bread making. Articles that focus only on nutritional aspects such as protein or starch digestibility and glycemic index (Cornejo et al., 2015; Wolter et al., 2013, 2014a) or antioxidant capacity (Sakac et al., 2011) were not included in the tables, as well as articles focusing only on the chemical composition (Costantini et al., 2014; de la Barca et al., 2010; Krupa-Kozak et al., 2011b; Wronkowska et al., 2010).

3.1 Gluten-free bread recipes

Each table lists the composition of the standard recipe, including flour or starch source(s) used and additives present both in control and tested sample. In recipes based on pure starches (Table 2), maize and potato starches are commonly combined. Some articles used only maize starch or a mix of maize and another starch. Rarely used starch sources were gluten-free wheat and rice. 'Alternative flours' (Table 3) include those from gluten-free cereal flours other than rice such as oat, corn, sorghum, millet and teff, from pseudocereals such as buckwheat, amaranth and quinoa, from tubers such as cassava and potato, from legumes such as soy and chickpea and from other raw materials such as chestnut, tigernut, and chia. In recipes with a combination of different flours and starches as basic ingredients (Table 4), rice flour was often combined with cassava, potato or corn starch. Wheat starch, sorghum flour and flour from pseudocereals such as amaranth, buckwheat and quinoa were also used. In recipes with sourdough (Table 5), different flours, starches and combinations thereof were used.

Hydrocolloids were often used as improvers in bread based on rice flour, the most common one being hydroxypropyl methylcellulose (HPMC) but also carboxymethylcellulose (CMC) and methylcellulose (MC). A combination of guar gum and pectin was often used as additive in starch bread. Other commonly used gums were xanthan gum and locust bean gum. Pectin was also used as such or in combination with inulin or calcium citrate. Egg white, whey protein, zein and soy flour were used as protein sources. Enzymes such as transglutaminase (TGase), α-amylase and maltogenic amylase were included in the standard recipe in a few cases. Other additives were psyllium fiber, maltodextrins, ascorbic acid, lecithin and emulsifiers such as diacetyl tartaric acid ester of mono- and diglycerides (DATEM) and sodium stearoyl lactylate (SSL). In recipes with alternative flours and sourdough an additive was needed less often to obtain a control bread of reasonable quality.

Variables in the experimental setup include different additional ingredients, different properties or treatments of flour or starch and variations in the bread making procedure. Variable additives were alternative gluten-free flours and starches, seeds, hydrocolloids, gums and emulsifiers, fibers, proteins and enzymes. Buckwheat, carob, quinoa, amaranth, tigernut, chickpea and yam flour were added as alternative flours. As starch sources, cassava and chestnut starch were varied in the experimental setup. Seeds from chia, strawberry and blackcurrant were also added. Hydrocolloids and gums were HPMC, gelatin, carrageenan, alginate, tragacanth gum, locust bean gum, guar gum and xanthan gum. Fiber sources were β-glucan (from barley or oat), psyllium, pectin, inulin, fructans, polydextrose and fibers from bamboo, potato, pea and sugar beet. Protein sources include soy, pea and whey protein, zein, casein, egg white, collagen and bovine plasma protein. Enzymes such as TGase, different types of peptidases, glucose oxidase, laccase, xylanase, tyrosinase and amyloglucosidase were added to modify protein characteristics. Other variable additives were iron sources, apple and orange pomace, green plantain flour, acids, NaH_2PO_4 and glutathione. Different varieties of rice and oat flour, rice grain sizes and flour particle sizes were tested. Treatments include extrusion, high pressure treatment and steaming or roasting of flour and the use of modified starch. The breadmaking procedure was adapted by varying the mixer type and mixing time, and baking in a conventional oven was compared to infrared microwave baking.

The water level added was very variable, ranging from 50 to 218 %. For rice bread, most recipes used a water content between 70 and 110%. In starch breads, a water content of 90-110 % was commonly used. Recipes based on alternative gluten-free flours commonly used a water content of 100 % or higher. Recipes based on a combination of flours and starches generally includes less water, ranging between 70 and 100 %. In recipes containing sourdough, usually around 95 % of water was added.

3.2 Analyses of batter/dough and bread

Tables 1 to 5 also list analyses performed on the batter/dough and bread, which will be discussed separately for each Table.

Table 1 lists the recipes based on **rice flour**. In 34 research articles, this was the sole starch containing ingredient. In 20 articles, properties of the batter/dough and bread were studied. Three articles only studied batter/dough properties, while in the remainder only the bread was analyzed (see Table 1). The analyses performed on batter/dough are grouped for frequently used analyses. Rheology measurements are commonly performed on gluten-free batter/dough. Small deformation measurements are usually frequency sweep and creep-recovery tests, and were done in nine articles (Blanco et al., 2011; Demirkesen et al., 2010b; Mancebo et al., 2015; Martinez et al., 2014b; Pongjaruvat et al., 2014; Ronda et al., 2013; 2014; Torbica et al., 2010; Tsatsaragkou et al., 2014b). Large deformation measurements include extrusion tests, texture profile analysis (TPA), uniaxial extension tests and resistance to penetration. Four articles studied large deformation rheology (Buresova et al., 2014; Han et al., 2012; Ronda et al., 2013; Storck et al., 2013). Carbon dioxide production and height development during fermentation were measured by means of rheofermentometer analysis in four studies (de la Hera et al., 2013a; 2014; Gomez et al., 2013; Steffolani et al., 2014). The pasting behavior of batters/doughs during heating, by Rapid Visco Analyzer (RVA) or Mixolab analysis were studied in ten articles (see Table 1). Protein analysis was done by SDS-PAGE (Hatta et al., 2015; Kawamura-Konishi et al., 2013; Yano, 2010, 2012; Yano et al., 2013). Torbica et al. (2010) and Han et al. (2012) used differential scanning calorimetry (DSC) to assess starch gelatinization. The batter/dough structure was studied by microscopy (Kawamura-Konishi et al., 2013; Martinez et al., 2014b; Yano et al., 2013). Storck et al. (2013) measured batter/dough color.

Table 1 also lists techniques for evaluating quality aspects of rice bread. Loaf weight and volume analyses are standard and not included in the table. The main analysis of bread crumb is that of texture. Typically a two-bite-test (TPA) is used, but sometimes a single compression test is carried out. Twenty-five articles analyzed the texture of the bread crumb, of which seven monitored its evolution during storage (see Table 1). The storage time varied from one to nine days. Ronda and Roos (2011) and Hager et al. (2014) monitored starch retrogradation during bread ageing by DSC analysis. Hager et al. (2014) used proton nuclear magnetic resonance (^{1}H-NMR) to study changes in water distribution during storage. Crumb structure has been examined by two-dimensional (2D) image analysis (Blanco et al., 2011; Furlan et al., 2015; Hager et al., 2012; Hager and Arendt, 2013; Pongjaruvat et al., 2014; Shin et al., 2010; Tsatsaragkou et al., 2012; 2014a) or micro computed tomography analysis (Demirkesen et al., 2014), and on a smaller scale by scanning electron microscopy (SEM) (Furlan et al., 2015; Hager et al., 2012; Hatta et al., 2015; Kawamura-Konishi et al., 2013; Park et al., 2014; Yano, 2010, 2012). Other common experiments were measurement of crust and/or crumb color (Furlan et al., 2015; Kawamura-Konishi et al., 2013; Park et al., 2014; Perez-Quirce et al., 2014; Pongjaruvat et al., 2014; Steffolani et al., 2014) and crumb porosity (Tsatsaragkou et al., 2014a). Because achieving an acceptable taste is often a challenge in gluten-free bread making, sensory analysis has commonly been performed on rice bread (see Table 1). Yano and coworkers (2012; 2013) used headspace gas chromatography for analyzing the odorous compounds in bread.

Table 2 lists 22 recipes based on **pure starches**. The variability in analyses of starch batters/doughs was less extensive than for rice batter/dough. Small deformation rheology was measured in nine out of 22 references (Aguilar et al., 2015; Juszczak et al., 2012; Korus et al., 2012; Minarro et al., 2012; van Riemsdijk et al., 2011a; 2011b; Witczak et al., 2010; 2012; Ziobro et al., 2013b). Large deformation was used four times (Korus et al., 2012; Seguchi et al., 2012; van Riemsdijk et al., 2011a; 2011b). The pasting properties in batter/dough during heating as measured by RVA or Mixolab were determined by Witczak et al. (2010; 2012), Juszczak et al. (2012) and Krupa-Kozak et al. (2012; 2013). Rheofermentometer (Aguilar et al., 2015; Mariotti et al., 2013; Minarro et al., 2012) as well as DSC (Juszczak et al., 2012; Witczak et al., 2012; Wronkowska et al., 2013) analyses were performed in three cases. Schober et al. (2010) and van Riemsdijk et al. (2011b) visualized protein structures by microscopy.

Bread crumb texture measurement was again the most common analysis method (16 out of 22 articles). Eleven of these also monitored crumb hardening during storage from one to ten days (see Table 2). In five articles, starch retrogradation was examined by DSC (Krupa et al., 2010; Witczak et al., 2010; Ziobro et al., 2012; 2013a; 2013b). Sensory evaluation was performed in six studies (Kittisuban et al., 2014; Korus et al., 2012; Krupa-Kozak et al., 2011a; 2012; Minarro et al., 2012; Ziobro et al., 2013b). Crumb structure was studied by image analysis in ten articles and visual aspects by measurement of crumb and/or crust color in 11 articles (see Table 2). Other bread analyses were those of starch and protein (Krupa et al., 2010), dietary fiber and polyphenol (Korus et al., 2012) or calcium (Krupa-Kozak et al., 2012) contents, RVA pasting behavior of dried crumb (Krupa et al., 2010), crumb porosity (Korus et al., 2012), water activity (Krupa-Kozak et al., 2013; Mariotti et al., 2013), confocal laser scanning microscopy (CLSM) and microbiological load (Minarro et al., 2012), and *in vitro* protein digestibility (Smerdel et al., 2012).

Table 3 lists 29 recipes based on **'alternative flours'**. For batter/dough, the most performed analyses were small deformation rheology (11 articles) and measurement of batter/dough properties during heating by RVA or Mixolab (ten articles, see Table 3). Large deformation rheology was performed in six papers (Buresova et al., 2014; Flander et al., 2011; Londono et al., 2015; Onyango et al., 2011b; Sciarini et al., 2010a, b), and rheofermentometer analysis in three (de la Hera et al., 2013b; Hager et al., 2012; Renzetti et al., 2010). Sciarini et al. (2010b) and Demirkesen et al. (2013a) studied starch gelatinization by DSC analysis. The batter/dough structure was visualized by SEM (Huttner et al., 2010c; Peressini et al., 2011), CLSM (Han et al., 2013) or bright field microscopy (Huttner et al., 2010c). Other analyses performed on batter/dough (extracts) were SDS-PAGE and quantification of free amino groups (Han et al., 2013), measurement of water holding capacity (Ruhmkorf et al., 2012) and pH (Shin et al., 2013).

Twenty-three articles analysed crumb texture, and 13 of them monitored crumb hardening during bread storage (see Table 3). In four articles, starch retrogradation was monitored during bread storage by DSC (Demirkesen et al., 2013a; 2014; Hager et al., 2014; Sciarini et al., 2012a). ^{1}H-NMR was used by Hager et al. (2014) to study changes in water distribution during storage. Hager et al. (2012) measured the water activity of bread crumb and determined the microbial shelf-life. The crumb structure was visualized in seven articles by 2D image analysis (Demirkesen et al., 2013b; 2014; Hager et al., 2012; Hager and Arendt, 2013; Ruhmkorf et al., 2012; Sciarini et al., 2010a; 2012a; Shin et al., 2013), and the crumb and/or crust color were measured in eight articles (Demirkesen et al., 2010a; 2011; 2013a; Huttner et al., 2010a, c; Kim and Yokoyama, 2011; Sciarini et al., 2010a, b). The microstructure of crumb was assessed using SEM by Hager et al. (2012) and Demirkesen et al. (2013b), CLSM by Renzetti et al. (2010) or X-ray analysis and Fourier transform infrared spectroscopy analysis by Demirkesen et al. (2014). Renzetti et al. (2010) analysed the proteins by capillary electrophoresis. Sensory analysis was performed in five studies (Demirkesen et al., 2010a; Hager et al., 2012; Kim and Yokoyama, 2011; Pasqualone et al., 2010; Shin et al., 2013).

Table 4 lists 37 recipes with a **combination of different flours and starches** as basic ingredients. Small deformation rheological measurements of batter/dough were performed in 15 articles (see Table 4). Large deformation was measured in six articles (Andersson et al., 2011; Leray et al., 2010; O'Shea et al., 2013; Sciarini et al., 2012b; Trappey et al., 2015; Velazquez et al., 2012), and the properties of batter/dough during heating by RVA or

Mixolab in three (Alvarez-Jubete et al., 2010; Matos and Rosell, 2013; O'Shea et al., 2013). Rheofermentometer analysis was done in three articles (Cappa et al., 2013; Foste et al., 2014; Martinez et al., 2014a). Five articles used DSC analysis (Crockett et al., 2011a, b; Leray et al., 2010; Sabanis and Tzia, 2011b; Sciarini et al., 2012b). Crockett et al. (2011a, b) studied water distribution in batter/dough by thermogravimetric analysis. The batter/dough structure was subjected to image analysis (Cappa et al., 2013), SEM (Martinez et al., 2014a; O'Shea et al., 2013) or CLSM (Andersson et al., 2011; O'Shea et al., 2013).

Thirty-two studies measured crumb texture, 16 of which monitored the changes during storage from one to eight days (see Table 4). Purhagen et al. (2012) used DSC to study starch retrogradation and ^{1}H-NMR to study changes in water distribution during storage. The crumb structure was visualized by 2D image analysis in 14 articles and crumb or crust color was measured in 15 references (see Table 4). Dluzewska et al. (2015) determined the crumb porosity. Its microstructure was visualized by SEM (Alvarez-Jubete et al., 2010; O'Shea et al., 2013; Sabanis and Tzia, 2011a, b) or CLSM (Alvarez-Jubete et al., 2010; Hager et al., 2011; Minarro et al., 2010; O'Shea et al., 2013). Kiskini et al. (2010, 2012) measured the crust texture. Sensory analysis was performed in 21 articles (see Table 4). Rarely used analyses were those of chemical composition (Hager et al., 2011; Matos and Rosell, 2013; Phimolsiripol et al., 2012; Sarawong et al., 2014), dietary fiber (Capriles and Arêas, 2013; O'Shea et al., 2015; Phimolsiripol et al., 2012), glycemic response (Capriles and Arêas, 2013) or microbiological load (Minarro et al., 2010).

Table 5 lists 12 recipes wherein the application of **sourdough** was compared to a control recipe without sourdough or wherein different yeast strains were applied. Much as in Tables 1 to 4, the most common analysis on batter/dough was small deformation rheology (Capuani et al., 2014; Falade et al., 2014; Galle et al., 2012; Huttner et al., 2010b; Moroni et al., 2011;

Wolter et al., 2014b, c). Further, some analyses were typical for studies with sourdough: pH of the batter/dough was measured in six articles (Capuani et al., 2014; Galle et al., 2012; Huttner et al., 2010b; Moroni et al., 2011; Novotni et al., 2012; Wolter et al., 2014c), and four articles analyzed proteins by capillary gel electrophoresis (Capuani et al., 2014; Huttner et al., 2010b; Moroni et al., 2011; Wolter et al., 2014c). Large deformation rheology was only measured in two cases (Falade et al., 2014; Hamada et al., 2013). Two papers mentioned the use of rheofermentometer analysis (Galle et al., 2012; Moroni et al., 2011) and batter/dough properties during heating (Edema et al., 2013; Hamada et al., 2013). Rarely used analyses were lactic acid bacteria determination (Huttner et al., 2010b), protein analysis by SDS-PAGE (Hamada et al., 2013), DSC and CLSM (Falade et al., 2014) and analysis of sourdough metabolites and antifungal compounds (Axel et al., 2015).

Ten studies analysed bread texture, and eight of them monitored the evolution of crumb texture during storage (see Table 5). Wolter et al. (2014c) and Axel et al. (2015) also assessed the microbial shelf-life. 2D image analysis was performed in six articles (Axel et al., 2015; Capuani et al., 2014; Falade et al., 2014; Rozylo et al., 2015; Wolter et al., 2014b, c), Wolter et al. (2014b) and Falade et al. (2014) also examined the microstructure of the bread crumb by SEM or CLSM, respectively. Crust and crumb color were measured by Huttner et al. (2010b), while Edema et al. (2013) assessed the crumb texture only visually. Wolter et al. (2014b, c) and Rozylo et al. (2015) analyzed the sensory properties of bread. In four articles, bread pH was determined (Galle et al., 2012; Moroni et al., 2011; Novotni et al., 2012; Rozylo et al., 2015) and Novotni et al. (2012) also measured the lactic and acetic acid concentrations. They also performed chemical analysis, measured pasting properties and the *in vivo* glycemic index.

Overall, the research on gluten-free bread is very divergent. The above clearly shows the variability in the composition of the recipes, the raw materials and additives used. Even within one flour source, variability is considerable. Furthermore, a conventional widely used bread making procedure [like the 'straight dough' process (Finney, 1984) for wheat bread] does not exist for gluten-free bread and as a result a broad range of water levels, mixing times and fermentation steps are used. The techniques used for analyzing batter/dough and bread also vary widely, which emerged from the above. These factors make it difficult to compare results obtained by different research groups, even within the limited amount of research dealing with the same starting materials.

4. Looking forward

Dough/batter properties and quality parameters of breads have been extensively assessed. However it has been difficult to draw conclusions about the ideal properties of gluten-free systems (Matos and Rosell, 2015). There thus is only scarce information about the relationships between dough/batter characteristics and bread quality. A recent study compiled data on dough/batter characteristics and bread quality from seven previous reports comprising 65 different gluten-free recipes (Matos and Rosell, 2015). Visco-elastic moduli, pasting properties (RVA) and Mixolab parameters collected from the reported gluten-free dough/batter properties were pooled and correlated with specific volume and crumb parameters of the resulting breads. Only for the reported Mixolab parameters they found strong correlations with TPA parameters of bread. TPA hardness was strongly correlated with parameters characterizing hydration during mixing (Mixolab parameter 'C_1'), set-back during cooling (Mixolab parameter 'C_5-C_4') and end-viscosity after cooling to 50°C (Mixolab parameter 'C_5'). Cohesiveness was highly negatively correlated with 'C_1' [maximum torque during mixing (used to determine water absorption)] and positively correlated with 'C_5-C_4' [set-back during cooling to 50 °C]. Conversely, springiness was strongly positively correlated with 'C_1' and negatively with 'C_5-C_4'. Likely due to the low number of data available from published manuscripts, no significant correlations were found between bread texture parameters and the visco-elastic moduli or the RVA pasting parameters previously reported for different gluten-free doughs/batters.

To link batter/dough parameters with bread characteristics the transition from dough/batter to bread can be studied by monitoring the changes in the batter/dough during the different processing steps. Crucial in understanding the changes is a thorough characterization of all ingredients and of the interactions between ingredients.

4.1 Fermentation phase

During fermentation, the gas produced by yeast causes expansion of the gas cells previously incorporated into the batter/dough during the mixing phase (Delcour and Hoseney, 2010). Since the stability and the growth of gas bubbles generated determines the volume of the bread loaf as well as the product texture, any modification during the fermentation phase can alter the crumb structure of the product (He and Hoseney, 1991).

To improve the knowledge about the fermentation phase, dynamic monitoring of variables such as volume, density, bubble size and distribution can be very helpful. Rheofermentometer analysis to study volume increase and gas release has already been included in several studies on gluten-free bread. However, techniques aiming at imaging the batter/dough structure have not been used commonly in this field. In wheat bread dough research, in the last decade various techniques have been used to study the fermentation phase. These have included ultrasound (Elmehdi et al., 2003; Skaf et al., 2009), magnetic resonance imaging (MRI) (Bonny et al., 2004; De Guio et al., 2009; Rouille et al., 2005), CLSM (Boitte et al., 2013; Upadhyay et al., 2012), 2D imaging (Romano et al., 2013), X-ray tomography (Lampignano et al., 2013; Turbin-Orger et al., 2012) and a 3D vision system based on structured light (Verdu et al., 2015). By applying them on gluten-free batter/dough useful information about its evolution and the critical stages for gas release during fermentation phase can be obtained.

4.2 Baking phase

Traditionally, bread is baked in an oven in which dough or batter is heated progressively from the outside toward the center. During baking, a temperature gradient exists from the outside to the center of the bread. The extent to which temperature-triggered reactions such as protein polymerization, starch gelatinization and pasting occur in a particular part of the dough or batter during the baking process depends on the temperature−time profile experienced by that part in the baking tin. This makes the study of the changes in dough/bread during heating very difficult. This problem can be addressed using an electrical resistance oven (ERO), in which dough or batter is heated uniformly (Baker, 1939). In such oven, dough or batter placed between two electrode plates serves as an electrical resistance and heat is generated by an electric field. As a result, it is uniformly heated and the resultant bread has no crust. The heating rate can be controlled by adjusting the distance between the electrodes, the applied voltage, and the dough area in contact with the electrodes (Hayman et al., 1998; Hoseney, 1986). Wheat bread baked in an ERO using the same time-temperature profile as that in the center of a conventionally baked dough/bread shows indeed almost no temperature or moisture gradient. During storage starch retrogradation occurs to the same extent in both types of bread (Derde et al., 2014). Similar results have been obtained for cake where during conventional baking temperature gradients induce moisture gradients (Wilderjans et al., 2013). That the increase in crumb firmness of conventionally baked cakes during storage is much higher than that of ERO cakes is because crumb to crust moisture migration significantly contributes to firming of conventional cake crumb. This moisture migration occurs less in ERO cakes due to the absence of a crust (Luyts et al., 2013a). A combination of ERO and continuous oscillatory rod viscometry has been used to monitor changes in cake batter viscosity during baking. A decrease in viscosity early in heating and a subsequent rapid increase, due to starch gelatinization, was seen. The evolution of batter viscosity during the course of heating was affected in different ways by ingredients such as sugar type, shortening, egg white, hydrocolloids and emulsifiers (Shelke et al., 1990). Similar studies on gluten-free batter/dough may well help to open the "black box" which the baking step presents. Knowing the impact of different ingredients on viscosity development during baking will be very helpful in understanding the effect of these ingredients on end product quality. Another way to monitor flow properties during heating is by temperature sweep rheometer tests. This technique has already been applied in gluten-free bread making research by a few authors (Falade et al., 2014; Onyango et al., 2011a; Schober et al., 2010; Vallons et al., 2010).

Time domain (TD) ^{1}H-NMR is another interesting technique to open up the "black box" of the baking phase. It provides information on the molecular mobility of water and biopolymers (van Duynhoven et al., 2010) and is based on the ability of ^{1}H to absorb energy applied by a rotating magnetic field in an external static magnetic field. The time necessary for ^{1}H to lose the absorbed energy and return to its equilibrium state is very sensitive to molecular mobility of water and/or biopolymers in the sample (Ablett, 1992; Schmidt, 2007). TD ^{1}H-NMR detects and reflects differences in ^{1}H mobility of water and biopolymers based on the environment the protons are in (Tang et al., 2000). This has already allowed studying water and biopolymer ^{1}H mobility in wheat based food products including dough (Doona and Baik, 2007; Ruan et al., 1999), cake (Le Grand et al., 2007; Luyts et al., 2013b) and bread (Bosmans et al., 2013; Chen et al., 1997; Curti et al., 2011; Wang et al., 2004). Limited research on the molecular mobility of water and biopolymers in gluten-free bread was done using TD ^{1}H-NMR (Hager et al., 2014; Purhagen et al., 2012). However, all aforementioned studies focus on the ^{1}H mobility of starch, proteins and/or water before and after heating or during storage, but not on how this ^{1}H mobility changes during the heating phase, which at the moment presents a "black box". One promising way to open it is to use temperature controlled ^{1}H-NMR (Engelsen et al., 2001) to investigate the temperature dynamics in biopolymer and water mobility during heating. This technique has been used to study mobility dynamics of hydrated starches of other origins (rice, potatoes, peas, etc.) upon heating (Fan et al., 2013; Ritota et al., 2008; Tananuwong and Reid, 2004; Tang et al., 2001) or of more complex wheat based doughs for biscuits (Assifaoui et al., 2006) or bread (Rondeau-Mouro et al., 2015).

Furthermore, some of the imaging techniques mentioned above can be applied during heating: X-ray tomography (Babin et al., 2006) and magnetic resonance microscopy (Bajd and Sersa, 2011). By including the baking phase, the whole bread making procedure can be monitored real time from batter/dough to baked bread. By studying the impact of adaptation to the recipes during this real time monitoring, the quality determining factors of gluten-free bread can be identified.

4.3 Fresh and stored bread

Various factors play critical roles in the firming (staling) of baked goods during storage. These include amylopectin recrystallization, changes in amorphous domains and interactions among other bread components (e.g., proteins and lipids). The key to these changes is distribution of water (Chen et al., 1997). ^{1}H-NMR and MRI are two nondestructive techniques that enable detection of (changes in) the distribution and mobility of water and in the structure of the food matrix in fresh bread and during storage (Ruan et al., 1996). ^{1}H-NMR requires only very small samples and, therefore, relates to specific portions of a bread loaf. MRI provides additional information on the spatial distribution of water content since the whole loaf of bread can be imaged and analyzed in a noninvasive and nondestructive fashion. Moisture gradients and their changes during bread storage can be surveyed. Only two references mention proton redistribution during gluten-free bread storage by ^{1}H-NMR (Hager et al., 2014; Purhagen et al., 2012). This technique can be much further exploited for evaluating the impact of different ingredients on the molecular water dynamics in fresh bread and during bread storage. Furthermore, MRI has not been applied in the field of gluten-free bread making. Information on the impact of different ingredients on the spatial (re)distribution of water in fresh bread and during bread storage can help improving the quality of gluten-free bread. For example, water proton distribution throughout wheat bread loaves supplemented with soy flour, studied with MRI, was very homogeneous in fresh breads, with minimal water migration occurring during prolonged storage. In contrast, traditional wheat bread displayed an inhomogeneous water proton population that tended to change (with higher moisture migration towards the outer perimeter of the slice) during storage (Lodi et al., 2007).

Taste and mouthfeel are key to bread quality. Sensory analysis has been performed in studies on gluten-free bread (Table 1-5). However, mostly only sensory analysis of fresh bread has been performed, while fast bread staling is one of the major problems in gluten-free bread making. Next to sensory analysis with a trained sensory panel, sensory data can be acquired analytically. Aroma compounds in the crust and the crumb can be identified by Aroma Extract Dilution Analysis and quantified by stable isotope dilution assays (Schieberle and Hofmann, 2012). The ratio of concentration to odor threshold provides the aroma value. Furthermore, a model mouth using a defined amount of bread mixed with human saliva and simulation of mastication (Pflaum et al., 2013) can be coupled with proton-transfer-reaction mass-spectrometry (Buettner et al., 2008; Heenan et al., 2012) to analyze the release of odorants from bread crust and crumb inline. Comparison with wheat bread can be used to steer the gluten-free recipe to approach this desired aroma profile.

Together with the information retrieved with traditional techniques, applying these new techniques in gluten-free bread making can reasonably be accepted to increase our understanding of the structure formation, staling and sensory characteristics of gluten-free bread.

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References

Ablett, S., 1992. Overview of NMR applications in food sciences. Trends in Food Science & Technology 3, 246-250.

Aguilar, N., Albanell, E., Minarro, B., Capellas, M., 2015. Chickpea and tiger nut flours as alternatives to emulsifier and shortening in gluten-free bread. Lwt-Food Science and Technology 62, 225-232.

Alvarez-Jubete, L., Auty, M., Arendt, E.K., Gallagher, E., 2010. Baking properties and microstructure of pseudocereal flours in gluten-free bread formulations. European Food Research and Technology 230, 437-445.

Andersson, H., Ohgren, C., Johansson, D., Kniola, M., Stading, M., 2011. Extensional flow, viscoelasticity and baking performance of gluten-free zein-starch doughs supplemented with hydrocolloids. Food Hydrocolloids 25, 1587-1595.

Anton, A.A., Artfield, S.D., 2008. Hydrocolloids in gluten-free breads: A review. International Journal of Food Sciences and Nutrition 59, 11-23.

Aoki, N., Umemoto, T., Okamoto, K., Suzuki, Y., Tanaka, J., 2015. Mutants that have shorter amylopectin chains are promising materials for slow-hardening rice bread. Journal of Cereal Science 61, 105-110.

Arendt, E.K., Ryan, L.A.M., Dal Bello, F., 2007. Impact of sourdough on the texture of bread. Food Microbiology 24, 165-174.

Assifaoui, A., Champion, D., Chiotelli, E., Verel, A., 2006. Characterization of water mobility in biscuit dough using a low-field H-1 NMR technique. Carbohydrate Polymers 64, 197-204.

Axel, C., Rocker, B., Brosnan, B., Zannini, E., Furey, A., Coffey, A., Arendt, E.K., 2015. Application of *Lactobacillus amylovorus* DSM19280 in gluten-free sourdough bread to improve the microbial shelf life. Food Microbiology 47, 36-44.

Babin, P., Della Valle, G., Chiron, H., Cloetens, P., Hoszowska, J., Pernot, P., Reguerre, A.L., Salvo, L., Dendievel, R., 2006. Fast X-ray tomography analysis of bubble growth and foam setting during breadmaking. Journal of Cereal Science 43, 393-397.

Bajd, F., Sersa, I., 2011. Continuous monitoring of dough fermentation and bread baking by magnetic resonance microscopy. Magnetic Resonance Imaging 29, 434-442.

Baker, J.C., 1939. A method and apparatus for testing doughs. Cereal Chemistry 16, 513-517.

Blanco, C.A., Ronda, F., Perez, B., Pando, V., 2011. Improving gluten-free bread quality by enrichment with acidic food additives. Food Chemistry 127, 1204-1209.

Boitte, J.B., Hayert, M., Michon, C., 2013. Observation of wheat flour doughs under mechanical treatment using confocal microscopy and classification of their microstructures. Journal of Cereal Science 58, 365-371.

Bonny, J.M., Rouille, J., Della Valle, G., Devaux, M.F., Douliez, J.P., Renou, J.P., 2004. Dynamic magnetic resonance microscopy of flour dough fermentation. Magnetic Resonance Imaging 22, 395-401.

Bosmans, G.M., Lagrain, B., Ooms, N., Fierens, E., Delcour, J.A., 2013. Biopolymer interactions, water dynamics, and bread crumb firming. Journal of Agricultural and Food Chemistry 61, 4646-4654.

Buettner, A., Otto, S., Beer, A., Mestres, M., Schieberle, P., Hummel, T., 2008. Dynamics of retronasal aroma perception during consumption: Cross-linking on-line breath analysis with medico-analytical tools to elucidate a complex process. Food Chemistry 108, 1234-1246.

Buresova, I., Kracmar, S., Dvorakova, P., Streda, T., 2014. The relationship between rheological characteristics of gluten-free dough and the quality of biologically leavened bread. Journal of Cereal Science 60, 271-275.

Cappa, C., Lucisano, M., Mariotti, M., 2013. Influence of Psyllium, sugar beet fibre and water on gluten-free dough properties and bread quality. Carbohydrate Polymers 98, 1657-1666.

Capriles, V.D., Arêas, J.A.G., 2011. Advances in the formulation of gluten-free breads: technological and nutritional aspects. Boletim Do Centro De Pesquisa De Processamento De Alimentos 29, 129-136.

Capriles, V.D., Arêas, J.A.G., 2013. Effects of prebiotic inulin-type fructans on structure, quality, sensory acceptance and glycemic response of gluten-free breads. Food & Function 4, 104-110.

Capriles, V.D., Arêas, J.A.G., 2014. Novel approaches in gluten-free breadmaking: interface between food science, nutrition, and health. Comprehensive Reviews in Food Science and Food Safety 13, 871-890.

Capuani, A., Behr, J., Arendt, E.K., Vogel, R.F., 2014. Impact of 'oxidizing' and 'reducing' buckwheat sourdoughs on brown rice and buckwheat batter and bread. European Food Research and Technology 238, 979-988.

Chen, P.L., Long, Z., Ruan, R., Labuza, T.P., 1997. Nuclear magnetic resonance studies of water mobility in bread during storage. Food Science and Technology-Lebensmittel-Wissenschaft & Technologie 30, 178-183.

Comino, I., Moreno, M.D., Real, A., Rodriguez-Herrera, A., Barro, F., Sousa, C., 2013. The gluten-free diet: testing alternative cereals tolerated by celiac patients. Nutrients 5, 4250-4268.

Cornejo, F., Caceres, P.J., Martinez-Villaluenga, C., Rosell, C.M., Frias, J., 2015. Effects of germination on the nutritive value and bioactive compounds of brown rice breads. Food Chemistry 173, 298-304.

Costantini, L., Luksic, L., Molinari, R., Kreft, I., Bonafaccia, G., Manzi, L., Merendino, N., 2014. Development of gluten-free bread using tartary buckwheat and chia flour rich in flavonoids and omega-3 fatty acids as ingredients. Food Chemistry 165, 232-240.

Crockett, R., Ie, P., Vodovotz, Y., 2011a. How do xanthan and hydroxypropyl methylcellulose individually affect the physicochemical properties in a model gluten-free dough? Journal of Food Science 76, E274-E282.

Crockett, R., Ie, P., Vodovotz, Y., 2011b. Effects of soy protein isolate and egg white solids on the physicochemical properties of gluten-free bread. Food Chemistry 129, 84-91.

Curti, E., Bubici, S., Carini, E., Baroni, S., Vittadini, E., 2011. Water molecular dynamics during bread staling by Nuclear Magnetic Resonance. Lwt-Food Science and Technology 44, 854-859.

De Guio, F., Musse, M., Benoit-Cattin, H., Lucas, T., Davenel, A., 2009. Magnetic resonance imaging method based on magnetic susceptibility effects to estimate bubble size in alveolar products: application to bread dough during proving. Magnetic Resonance Imaging 27, 577-585.

de la Barca, A.M.C., Rojas-Martinez, M.E., Islas-Rubio, A.R., Cabrera-Chavez, F., 2010. Gluten-free breads and cookies of raw and popped amaranth flours with attractive technological and nutritional qualities. Plant Foods for Human Nutrition 65, 241-246.

de la Hera, E., Martinez, M., Gomez, M., 2013a. Influence of flour particle size on quality of gluten-free rice bread. Lwt-Food Science and Technology 54, 199-206.

de la Hera, E., Talegon, M., Caballero, P., Gomez, M., 2013b. Influence of maize flour particle size on gluten-free breadmaking. Journal of the Science of Food and Agriculture 93, 924-932.

de la Hera, E., Rosell, C.M., Gomez, M., 2014. Effect of water content and flour particle size on gluten-free bread quality and digestibility. Food Chemistry 151, 526-531.

de Morais, E.C., Cruz, A.G., Bolini, H.M.A., 2013. Gluten-free bread: multiple time-intensity analysis, physical characterisation and acceptance test. International Journal of Food Science and Technology 48, 2176-2184.

de Morais, E.C., Cruz, A.G., Faria, J.A.F., Bolini, H.M.A., 2014. Prebiotic gluten-free bread: Sensory profiling and drivers of liking. Lwt-Food Science and Technology 55, 248-254.

Delcour, J.A., Hoseney, R.C., 2010. Principles of cereal science and technology, Third ed. AACC International Press, Minnesota, USA.

Demirkesen, I., Mert, B., Sumnu, G., Sahin, S., 2010a. Utilization of chestnut flour in gluten-free bread formulations. Journal of Food Engineering 101, 329-336.

Demirkesen, I., Sumnu, G., Sahin, S., Uysal, N., 2011. Optimisation of formulations and infrared-microwave combination baking conditions of chestnut-rice breads. International Journal of Food Science and Technology 46, 1809-1815.

Demirkesen, I., Sumnu, G., Sahin, S., 2013a. Quality of gluten-free bread formulations baked in different ovens. Food and Bioprocess Technology 6, 746-753.

Demirkesen, I., Sumnu, G., Sahin, S., 2013b. Image analysis of gluten-free breads prepared with chestnut and rice flour and baked in different ovens. Food and Bioprocess Technology 6, 1749-1758.

Demirkesen, I., Campanella, O.H., Sumnu, G., Sahin, S., Hamaker, B.R., 2014. A study on staling characteristics of gluten-free breads prepared with chestnut and rice flours. Food and Bioprocess Technology 7, 806-820.

Demirkesen, L., Mert, B., Sumnu, G., Sahin, S., 2010b. Rheological properties of gluten-free bread formulations. Journal of Food Engineering 96, 295-303.

Deora, N.S., Deswal, A., Mishra, H.N., 2014. Alternative approaches towards gluten-free dough development: recent trends. Food Engineering Reviews 6, 89-104.

Derde, L.J., Gomand, S.V., Courtin, C.M., Delcour, J.A., 2014. Moisture distribution during conventional or electrical resistance oven baking of bread dough and subsequent storage. Journal of Agricultural and Food Chemistry 62, 6445-6453.

Dluzewska, E., Marciniak-Lukasiak, K., Kurek, N., 2015. Effect of transglutaminase additive on the quality of gluten-free bread. Cyta-Journal of Food 13, 80-86.

Doona, C.J., Baik, M.Y., 2007. Molecular mobility in model dough systems studied by time-domain nuclear magnetic resonance spectroscopy. Journal of Cereal Science 45, 257-262.

Edema, M.O., Emmambux, M.N., Taylor, J.R.N., 2013. Improvement of fonio dough properties through starch modification by sourdough fermentation. Starch-Starke 65, 730-737.

Elgeti, D., Nordlohne, S.D., Foste, M., Besl, M., Linden, M.H., Heinz, V., Jekle, M., Becker, T., 2014. Volume and texture improvement of gluten-free bread using quinoa white flour. Journal of Cereal Science 59, 41-47.

Elmehdi, H.M., Page, J.H., Scanlon, M.G., 2003. Monitoring dough fermentation using acoustic waves. Food and Bioproducts Processing 81, 217-223.

Engelsen, S.B., Jensen, M.K., Pedersen, H.T., Norgaard, L., Munck, L., 2001. NMR-baking and multivariate prediction of instrumental texture parameters in bread. Journal of Cereal Science 33, 59-69.

Falade, A.T., Emmambux, M.N., Buys, E.M., Taylor, J.R.N., 2014. Improvement of maize bread quality through modification of dough rheological properties by lactic acid bacteria fermentation. Journal of Cereal Science 60, 471-476.

Falade, K.O., Akingbala, J.O., 2011. Utilization of cassava for food. Food Reviews International 27, 51-83.

Fan, D.M., Ma, S.Y., Wang, L.Y., Zhao, H.F., Zhao, J.X., Zhang, H., Chen, W., 2013. H-1 NMR studies of starch-water interactions during microwave heating. Carbohydrate Polymers 97, 406-412.

Finney, K.F., 1984. An optimized, straight-dough, bread-making method after 44 years. Cereal Chemistry 61, 20-27.

Flander, L., Holopainen, U., Kruus, K., Buchert, J., 2011. Effects of tyrosinase and laccase on oat proteins and quality parameters of gluten-free oat breads. Journal of Agricultural and Food Chemistry 59, 8385-8390.

Foste, M., Nordlohne, S.D., Elgeti, D., Linden, M.H., Heinz, V., Jekle, M., Becker, T., 2014. Impact of quinoa bran on gluten-free dough and bread characteristics. European Food Research and Technology 239, 767-775.

Furlan, L.T.R., Padilla, A.P., Campderros, M.E., 2015. Improvement of gluten-free bread properties by the incorporation of bovine plasma proteins and different saccharides into the matrix. Food Chemistry 170, 257-264.

Gallagher, E., Gormley, T.R., Arendt, E.K., 2004. Recent advances in the formulation of gluten-free cereal-based products. Trends in Food Science & Technology 15, 143-152.

Galle, S., Schwab, C., Dal Bello, F., Coffey, A., Ganzle, M.G., Arendt, E.K., 2012. Influence of in-situ synthesized exopolysaccharides on the quality of gluten-free sorghum sourdough bread. International Journal of Food Microbiology 155, 105-112.

Gobbetti, M., Rizzello, C.G., Di Cagno, R., De Angelis, M., 2007. Sourdough lactobacilli and celiac disease. Food Microbiology 24, 187-196.

Gomez, M., Talegon, M., De La Hera, E., 2013. Influence of mixing on quality of gluten-free bread. Journal of Food Quality 36, 139-145.
Hager, A.S., Ryan, L.A.M., Schwab, C., Ganzle, M.G., O'Doherty, J.V., Arendt, E.K., 2011. Influence of the soluble fibres inulin and oat beta-glucan on quality of dough and bread. European Food Research and Technology 232, 405-413.
Hager, A.S., Wolter, A., Czerny, M., Bez, J., Zannini, E., Arendt, E.K., Czerny, M., 2012. Investigation of product quality, sensory profile and ultrastructure of breads made from a range of commercial gluten-free flours compared to their wheat counterparts. European Food Research and Technology 235, 333-344.
Hager, A.S., Arendt, E.K., 2013. Influence of hydroxypropylmethylcellulose (HPMC), xanthan gum and their combination on loaf specific volume, crumb hardness and crumb grain characteristics of gluten-free breads based on rice, maize, teff and buckwheat. Food Hydrocolloids 32, 195-203.
Hager, A.S., Bosmans, G.M., Delcour, J.A., 2014. Physical and molecular changes during the storage of gluten-free rice and oat bread. Journal of Agricultural and Food Chemistry 62, 5682-5689.
Hamada, S., Suzuki, K., Aoki, N., Suzuki, Y., 2013. Improvements in the qualities of gluten-free bread after using a protease obtained from Aspergillus oryzae. Journal of Cereal Science 57, 91-97.
Han, H.M., Cho, J.H., Kang, H.W., Koh, B.K., 2012. Rice varieties in relation to rice bread quality. Journal of the Science of Food and Agriculture 92, 1462-1467.
Han, L.H., Cheng, Y.Q., Qiu, S., Tatsumi, E., Shen, Q., Lu, Z.H., Li, L.T., 2013. The effects of vital wheat gluten and transglutaminase on the thermomechanical and dynamic rheological properties of buckwheat dough. Food and Bioprocess Technology 6, 561-569.
Hatta, E., Matsumoto, K., Honda, Y., 2015. Bacillolysin, papain, and subtilisin improve the quality of gluten-free rice bread. Journal of Cereal Science 61, 41-47.
Hayman, D., Hoseney, R.C., Faubion, J.M., 1998. Effect of pressure (crust formation) on bread crumb grain development. Cereal Chemistry 75, 581-584.
He, H., Hoseney, R.C., 1991. Gas Retention of Different Cereal Flours. Cereal Chemistry 68, 334-336.
Heenan, S., Soukoulis, C., Silcock, P., Fabris, A., Aprea, E., Cappellin, L., Mark, T.D., Gasperi, F., Biasioli, F., 2012. PTR-TOF-MS monitoring of in vitro and in vivo flavour release in cereal bars with varying sugar composition. Food Chemistry 131, 477-484.
Hoseney, R.C., 1986. Component interaction during heating and storage of baked products. In: Blanshard, J.M.V., Frazier, P.J., Galliard, T. (Eds.), Chemistry and Physics of Baking. Royal Society of Chemistry, London, UK, p. 216–226.
Houben, A., Hochstotter, A., Becker, T., 2012. Possibilities to increase the quality in gluten-free bread production: an overview. European Food Research and Technology 235, 195-208.
Huttner, E.K., Arendt, E.K., 2010. Recent advances in gluten-free baking and the current status of oats. Trends in Food Science & Technology 21, 303-312.
Huttner, E.K., Dal Bello, F., Arendt, E.K., 2010a. Rheological properties and bread making performance of commercial wholegrain oat flours. Journal of Cereal Science 52, 65-71.
Huttner, E.K., Dal Bello, F., Arendt, E.K., 2010b. Identification of lactic acid bacteria isolated from oat sourdoughs and investigation into their potential for the improvement of oat bread quality. European Food Research and Technology 230, 849-857.
Huttner, E.K., Dal Bello, F., Arendt, E.K., 2010c. Fundamental study on the effect of hydrostatic pressure treatment on the bread-making performance of oat flour. European Food Research and Technology 230, 827-835.
Juszczak, L., Witczak, T., Ziobro, R., Korus, J., Cieslik, E., Witczak, M., 2012. Effect of inulin on rheological and thermal properties of gluten-free dough. Carbohydrate Polymers 90, 353-360.
Kawamura-Konishi, Y., Shoda, K., Koga, H., Honda, Y., 2013. Improvement in gluten-free rice bread quality by protease treatment. Journal of Cereal Science 58, 45-50.
Kim, Y., Yokoyama, W.H., 2011. Physical and sensory properties of all-barley and all-oat breads with additional hydroxypropyl methylcellulose (HPMC) beta-glucan. Journal of Agricultural and Food Chemistry 59, 741-746.

Kiskini, A., Kapsokefalou, M., Yanniotis, S., Mandala, I., 2010. Effect of different iron compounds on wheat and gluten-free breads. Journal of the Science of Food and Agriculture 90, 1136-1145.

Kiskini, A., Kapsokefalou, M., Yanniotis, S., Mandala, I., 2012. Effect of iron fortification on physical and sensory quality of gluten-free bread. Food and Bioprocess Technology 5, 385-390.

Kittisuban, P., Ritthiruangdej, P., Suphantharika, M., 2014. Optimization of hydroxypropylmethylcellulose, yeast (beta-glucan, and whey protein levels based on physical properties of gluten-free rice bread using response surface methodology. Lwt-Food Science and Technology 57, 738-748.

Korus, J., Juszczak, L., Ziobro, R., Witczak, M., Grzelak, K., Sojka, M., 2012. Defatted strawberry and blackcurrant seeds as functional ingredients of gluten-free bread. Journal of Texture Studies 43, 29-39.

Krupa-Kozak, U., Troszynska, A., Baczek, N., Soral-Smietana, M., 2011a. Effect of organic calcium supplements on the technological characteristic and sensory properties of gluten-free bread. European Food Research and Technology 232, 497-508.

Krupa-Kozak, U., Wronkowska, M., Soral-Smietana, M., 2011b. Effect of buckwheat flour on microelements and proteins contents in gluten-free bread. Czech Journal of Food Sciences 29, 103-108.

Krupa-Kozak, U., Altamirano-Fortoul, R., Wronkowska, M., Rosell, C.M., 2012. Breadmaking performance and technological characteristic of gluten-free bread with inulin supplemented with calcium salts. European Food Research and Technology 235, 545-554.

Krupa-Kozak, U., Baczek, N., Rosell, C.M., 2013. Application of dairy proteins as technological and nutritional improvers of calcium-supplemented gluten-free bread. Nutrients 5, 4503-4520.

Krupa, U., Rosell, C.M., Sadowska, J., Soral-Smietana, M., 2010. Bean starch as ingredient for gluten-free bread. Journal of Food Processing and Preservation 34, 501-518.

Kulamarva, A.G., Sosle, V.R., Raghavan, G.S.V., 2009. Nutritional and rheological properties of sorghum. International Journal of Food Properties 12, 55-69.

Lampignano, V., Laverse, J., Mastromatteo, M., Del Nobile, M.A., 2013. Microstructure, textural and sensorial properties of durum wheat bread as affected by yeast content. Food Research International 50, 369-376.

Le Grand, F., Cambert, M., Mariette, F., 2007. NMR signal analysis to characterize solid, aqueous, and lipid phases in baked cakes. Journal of Agricultural and Food Chemistry 55, 10947-10952.

Leray, G., Oliete, B., Mezaize, S., Chevallier, S., de Lamballerie, M., 2010. Effects of freezing and frozen storage conditions on the rheological properties of different formulations of non-yeasted wheat and gluten-free bread dough. Journal of Food Engineering 100, 70-76.

Lodi, A., Abduljalil, A.M., Vodovotz, Y., 2007. Characterization of water distribution in bread during storage using magnetic resonance imaging. Magnetic Resonance Imaging 25, 1449-1458.

Londono, D.M., Gilissen, L.J.W.J., Visser, R.G.F., Smulders, M.J.M., Hamer, R.J., 2015. Understanding the role of oat β-glucan in oat-based dough systems. Journal of Cereal Science 62, 1-7.

Luyts, A., Wilderjans, E., Van Haesendonck, I., Brijs, K., Courtin, C.M., Delcour, J.A., 2013a. Relative importance of moisture migration and amylopectin retrogradation for pound cake crumb firming. Food Chemistry 141, 3960-3966.

Luyts, A., Wilderjans, E., Waterschoot, J., Van Haesendonck, I., Brijs, K., Courtin, C.M., Hills, B., Delcour, J.A., 2013b. Low resolution H-1 NMR assignment of proton populations in pound cake and its polymeric ingredients. Food Chemistry 139, 120-128.

Mancebo, C.M., Miguel, M.A.S., Martinez, M.M., Gomez, M., 2015. Optimisation of rheological properties of gluten-free doughs with HPMC, psyllium and different levels of water. Journal of Cereal Science 61, 8-15.

Mariotti, M., Pagani, M.A., Lucisano, M., 2013. The role of buckwheat and HPMC on the breadmaking properties of some commercial gluten-free bread mixtures. Food Hydrocolloids 30, 393-400.

Martinez, M.M., Diaz, A., Gomez, M., 2014a. Effect of different microstructural features of soluble and insoluble fibres on gluten-free dough rheology and bread-making. Journal of Food Engineering 142, 49-56.

Martinez, M.M., Oliete, B., Roman, L., Gomez, M., 2014b. Influence of the Addition of Extruded Flours on Rice Bread Quality. Journal of Food Quality 37, 83-94.

Matos, M.E., Rosell, C.M., 2013. Quality indicators of rice-based gluten-free bread-like products: relationships between dough rheology and quality characteristics. Food and Bioprocess Technology 6, 2331-2341.

Matos, M.E., Rosell, C.M., 2015. Understanding gluten-free dough for reaching breads with physical quality and nutritional balance. Journal of the Science of Food and Agriculture 95, 653-661.

Mezaize, S., Chevallier, S., Le-Bail, A., de Lamballerie, M., 2010. Gluten-free frozen dough. Influence of freezing on dough rheological properties and bread quality. Food Research International 43, 2186-2192.

Milde, L.B., Ramallo, L.A., Puppo, M.C., 2012. Gluten-free Bread Based on Tapioca Starch: Texture and Sensory Studies. Food and Bioprocess Technology 5, 888-896.

Minarro, B., Normahomed, I., Guamis, B., Capellas, M., 2010. Influence of unicellular protein on gluten-free bread characteristics. European Food Research and Technology 231, 171-179.

Minarro, B., Albanell, E., Aguilar, N., Guamis, B., Capellas, M., 2012. Effect of legume flours on baking characteristics of gluten-free bread. Journal of Cereal Science 56, 476-481.

Moreira, R., Chenlo, F., Torres, M.D., 2011. Rheological properties of commercial chestnut flour doughs with different gums. International Journal of Food Science and Technology 46, 2085-2095.

Moreira, R., Chenlo, F., Torres, M.D., 2013. Rheology of gluten-free doughs from blends of chestnut and rice flours. Food and Bioprocess Technology 6, 1476-1485.

Moreira, R., Chenlo, F., Torres, M.D., Rama, B., 2014. Fine particle size chestnut flour doughs rheology: Influence of additives. Journal of Food Engineering 120, 94-99.

Moroni, A.V., Dal Bello, F., Zannini, E., Arendt, E.K., 2011. Impact of sourdough on buckwheat flour, batter and bread: Biochemical, rheological and textural insights. Journal of Cereal Science 54, 195-202.

Novotni, D., Cukelj, N., Smerdel, B., Bituh, M., Dujmic, F., Curic, D., 2012. Glycemic index and firming kinetics of partially baked frozen gluten-free bread with sourdough. Journal of Cereal Science 55, 120-125.

O'Shea, N., Doran, L., Auty, M., Arendt, E., Gallagher, E., 2013. The rheology, microstructure and sensory characteristics of a gluten-free bread formulation enhanced with orange pomace. Food & Function 4, 1856-1863.

O'Shea, N., Arendt, E., Gallagher, E., 2014. State of the art in gluten-free research. Journal of Food Science 79, R1067-R1076.

O'Shea, N., Rossle, C., Arendt, E., Gallagher, E., 2015. Modelling the effects of orange pomace using response surface design for gluten-free bread baking. Food Chemistry 166, 223-230.

Ohimain, E.I., 2015. Recent advances in the production of partially substituted wheat and wheatless bread. European Food Research and Technology 240, 257-271.

Omary, M.B., Fong, C., Rothschild, J., Finney, P., 2012. Effects of germination on the nutritional profile of gluten-free cereals and pseudocereals: a review. Cereal Chemistry 89, 1-14.

Onyango, C., Mutungi, C., Unbehend, G., Lindhauer, M.G., 2010a. Batter rheology and bread texture of sorghum-based gluten-free formulations modified with native or pregelatinised cassava starch and alpha-amylase. International Journal of Food Science and Technology 45, 1228-1235.

Onyango, C., Mutungi, C., Unbehend, G., Lindhauer, M.G., 2010b. Rheological and baking characteristics of batter and bread prepared from pregelatinised cassava starch and sorghum and modified using microbial transglutaminase. Journal of Food Engineering 97, 465-470.

Onyango, C., Mutungi, C., Unbehend, G., Lindhauer, M.G., 2011a. Rheological and textural properties of sorghum-based formulations modified with variable amounts of native or pregelatinised cassava starch. Lwt-Food Science and Technology 44, 687-693.

Onyango, C., Mutungi, C., Unbehend, G., Lindhauer, M.G., 2011b. Modification of gluten-free sorghum batter and bread using maize, potato, cassava or rice starch. Lwt-Food Science and Technology 44, 681-686.

Park, J.H., Kim, D.C., Lee, S.E., Kim, O.W., Kim, H., Lim, S.T., Kim, S.S., 2014. Effects of rice flour size fractions on gluten free rice bread. Food Science and Biotechnology 23, 1875-1883.

Parra, A.F.R., Ribotta, P.D., Ferrero, C., 2015. Apple pomace in gluten-free formulations: effect on rheology and product quality. International Journal of Food Science and Technology 50, 682-690.

Pasqualone, A., Caponio, F., Summo, C., Paradiso, V.M., Bottega, G., Pagani, M.A., 2010. Gluten-free bread making trials from cassava (*Manihot esculenta* Crantz) flour and sensory evaluation of the final product. International Journal of Food Properties 13, 562-573.

Peressini, D., Pin, M., Sensidoni, A., 2011. Rheology and breadmaking performance of rice-buckwheat batters supplemented with hydrocolloids. Food Hydrocolloids 25, 340-349.

Perez-Quirce, S., Collar, C., Ronda, F., 2014. Significance of healthy viscous dietary fibres on the performance of gluten-free rice-based formulated breads. International Journal of Food Science and Technology 49, 1375-1382.

Pflaum, T., Konitzer, K., Hofmann, T., Koehler, P., 2013. Analytical and Sensory Studies on the Release of Sodium from Wheat Bread Crumb. Journal of Agricultural and Food Chemistry 61, 6485-6494.

Phimolsiripol, Y., Mukprasirt, A., Schoenlechner, R., 2012. Quality improvement of rice-based gluten-free bread using different dietary fibre fractions of rice bran. Journal of Cereal Science 56, 389-395.

Pongjaruvat, W., Methacanon, P., Seetapan, N., Fuongfuchat, A., Gamonpilas, C., 2014. Influence of pregelatinised tapioca starch and transglutaminase on dough rheology and quality of gluten-free jasmine rice breads. Food Hydrocolloids 36, 143-150.

Purhagen, J.K., Sjoo, M.E., Eliasson, A.C., 2012. The anti-staling effect of pre-gelatinized flour and emulsifier in gluten-free bread. European Food Research and Technology 235, 265-276.

Rahaie, S., Gharibzahedi, S.M.T., Razavi, S.H., Jafari, S.M., 2014. Recent developments on new formulations based on nutrient-dense ingredients for the production of healthy-functional bread: a review. Journal of Food Science and Technology-Mysore 51, 2896-2906.

Renzetti, S., Courtin, C.M., Delcour, J.A., Arendt, E.K., 2010. Oxidative and proteolytic enzyme preparations as promising improvers for oat bread formulations: Rheological, biochemical and microstructural background. Food Chemistry 119, 1465-1473.

Ritota, M., Gianferri, R., Bucci, R., Brosio, E., 2008. Proton NMR relaxation study of swelling and gelatinisation process in rice starch-water samples. Food Chemistry 110, 14-22.

Romano, A., Cavella, S., Toraldo, G., Masi, P., 2013. 2D structural imaging study of bubble evolution during leavening. Food Research International 50, 324-329.

Ronda, F., Roos, Y.H., 2011. Staling of fresh and frozen gluten-free bread. Journal of Cereal Science 53, 340-346.

Ronda, F., Perez-Quirce, S., Angioloni, A., Collar, C., 2013. Impact of viscous dietary fibres on the viscoelastic behaviour of gluten-free formulated rice doughs: A fundamental and empirical rheological approach. Food Hydrocolloids 32, 252-262.

Ronda, F., Villanueva, M., Collar, C., 2014. Influence of acidification on dough viscoelasticity of gluten-free rice starch-based dough matrices enriched with exogenous protein. Lwt-Food Science and Technology 59, 12-20.

Rondeau-Mouro, C., Cambert, M., Kovrlija, R., Musse, M., Lucas, T., Mariette, F., 2015. Temperature-associated proton dynamics in wheat starch-based model systems and wheat flour dough evaluated by NMR. Food and Bioprocess Technology 8, 777-790.

Rouille, J., Bonny, J.M., Della Valle, G., Devaux, A.F., Renou, J.P., 2005. Effect of flour minor components on bubble growth in bread dough during proofing assessed by magnetic resonance imaging. Journal of Agricultural and Food Chemistry 53, 3986-3994.

Rozylo, R., Rudy, S., Krzykowski, A., Dziki, D., Gawlik-Dziki, U., Rozylo, K., Skonecki, S., 2015. Effect of adding fresh and freeze-dried buckwheat sourdough on gluten-free bread quality. International Journal of Food Science and Technology 50, 313-322.

Ruan, R., Almaer, S., Huang, V.T., Perkins, P., Chen, P., Fulcher, R.G., 1996. Relationship between firming and water mobility in starch-based food systems during storage. Cereal Chemistry 73, 328-332.

Ruan, R.R., Wang, X., Chen, P.L., Fulcher, R.G., Pesheck, P., Chakrabarti, S., 1999. Study of water in dough using nuclear magnetic resonance. Cereal Chemistry 76, 231-235.

Ruhmkorf, C., Rubsam, H., Becker, T., Bork, C., Voiges, K., Mischnick, P., Brandt, M.J., Vogel, R.F., 2012. Effect of structurally different microbial homoexopolysaccharides on the quality of gluten-free bread. European Food Research and Technology 235, 139-146.

Sabanis, D., Tzia, C., 2011a. Selected structural characteristics of HPMC-containing gluten free bread: a response surface methodology study for optimizing quality. International Journal of Food Properties 14, 417-431.

Sabanis, D., Tzia, C., 2011b. Effect of hydrocolloids on selected properties of gluten-free dough and bread. Food Science and Technology International 17, 279-291.

Sakac, M., Torbica, A., Sedej, I., Hadnadev, M., 2011. Influence of breadmaking on antioxidant capacity of gluten free breads based on rice and buckwheat flours. Food Research International 44, 2806-2813.

Sarawong, C., Gutierrez, Z.R., Berghofer, E., Schoenlechner, R., 2014. Effect of green plantain flour addition to gluten-free bread on functional bread properties and resistant starch content. International Journal of Food Science and Technology 49, 1825-1833.

Schamne, C., Dutcosky, S.D., Demiate, I.M., 2010. Obtention and characterization of gluten-free baked products. Ciencia E Tecnologia De Alimentos 30, 741-750.

Schieberle, P., Hofmann, T., 2012. Mapping the combinatorial code of food flavors by means of molecular sensory science approach. In: Jelen, H. (Ed.) Chemical and Functional Properties of Food Components Series. Food Flavors. Chemical, Sensory and Technologicyl Properties CRC Press, , Boca Raton, FL, USA, pp. 413-438

Schmidt, S.J., 2007. Water mobility in foods. In: Barbosa-Canovas, G.V., Schmidt, S.J., Labuza, T.P. (Eds.), Water activity in foods: fundamentals and applications. Blackwell Publishing, Ames, IA, USA.

Schober, T.J., Moreau, R.A., Bean, S.R., Boyle, D.L., 2010. Removal of surface lipids improves the functionality of commercial zein in viscoelastic zein-starch dough for gluten-free breadmaking. Journal of Cereal Science 52, 417-425.

Schoenlechner, R., Mandala, I., Kiskini, A., Kostaropoulos, A., Berghofer, E., 2010. Effect of water, albumen and fat on the quality of gluten-free bread containing amaranth. International Journal of Food Science and Technology 45, 661-669.

Sciarini, L.S., Ribotta, P.D., Leon, A.E., Perez, G.T., 2010a. Effect of hydrocolloids on gluten-free batter properties and bread quality. International Journal of Food Science and Technology 45, 2306-2312.

Sciarini, L.S., Ribotta, P.D., Leon, A.E., Perez, G.T., 2010b. Influence of gluten-free flours and their mixtures on batter properties and bread quality. Food and Bioprocess Technology 3, 577-585.

Sciarini, L.S., Perez, G.T., de Lamballerie, M., Leon, A.E., Ribotta, P.D., 2012a. Partial-baking process on gluten-free bread: impact of hydrocolloid addition. Food and Bioprocess Technology 5, 1724-1732.

Sciarini, L.S., Ribotta, P.D., Leon, A.E., Perez, G.T., 2012b. Incorporation of several additives into gluten free breads: Effect on dough properties and bread quality. Journal of Food Engineering 111, 590-597.

Seguchi, M., Ozawa, M., Nakamura, C., Tabara, A., 2012. Development of gluten-free bread baked with yam flour. Food Science and Technology Research 18, 543-548.

Shelke, K., Faubion, J.M., Hoseney, R.C., 1990. The dynamics of cake baking as studied by a combination of viscometry and electrical-resistance oven heating. Cereal Chemistry 67, 575-580.

Shin, D.J., Kim, W., Kim, Y., 2013. Physicochemical and sensory properties of soy bread made with germinated, steamed, and roasted soy flour. Food Chemistry 141, 517-523.

Shin, M., Gang, D.O., Song, J.Y., 2010. Effects of protein and transglutaminase on the preparation of gluten-free rice bread. Food Science and Biotechnology 19, 951-956.

Skaf, A., Nassar, G., Lefebvre, F., Nongaillard, B., 2009. A new acoustic technique to monitor bread dough during the fermentation phase. Journal of Food Engineering 93, 365-378.

Smerdel, B., Pollak, L., Novotni, D., Cukelj, N., Benkovic, M., Lusic, D., Curic, D., 2012. Improvement of gluten-free bread quality using transglutaminase, various extruded flours and protein isolates. Journal of Food and Nutrition Research 51, 242-253.
Smith, B.M., Bean, S.R., Herald, T.J., Aramouni, F.M., 2012. Effect of HPMC on the quality of wheat-free bread made from carob germ flour-starch mixtures. Journal of Food Science 77, C684-C689.
Steffolani, E., de la Hera, E., Perez, G., Gomez, M., 2014. Effect of chia (*Salvia hispanica* L) addition on the quality of gluten-free bread. Journal of Food Quality 37, 309-317.
Storck, C.R., Zavareze, E.D., Gularte, M.A., Elias, M.C., Rosell, C.M., Dias, A.R.G., 2013. Protein enrichment and its effects on gluten-free bread characteristics. Lwt-Food Science and Technology 53, 346-354.
Tananuwong, K., Reid, D.S., 2004. DSC and NMR relaxation studies of starch-water interactions during gelatinization. Carbohydrate Polymers 58, 345-358.
Tang, H.R., Godward, J., Hills, B., 2000. The distribution of water in native starch granules - a multinuclear NMR study. Carbohydrate Polymers 43, 375-387.
Tang, H.R., Brun, A., Hills, B., 2001. A proton NMR relaxation study of the gelatinisation and acid hydrolysis of native potato starch. Carbohydrate Polymers 46, 7-18.
Torbica, A., Hadnadev, M., Dapcevic, T., 2010. Rheological, textural and sensory properties of gluten-free bread formulations based on rice and buckwheat flour. Food Hydrocolloids 24, 626-632.
Trappey, E.F., Khouryieh, H., Aramouni, F., Herald, T., 2015. Effect of sorghum flour composition and particle size on quality properties of gluten-free bread. Food Science and Technology International 21, 188-202.
Tsatsaragkou, K., Yiannopoulos, S., Kontogiorgi, A., Poulli, E., Krokida, M., Mandala, I., 2012. Mathematical approach of structural and textural properties of gluten free bread enriched with carob flour. Journal of Cereal Science 56, 603-609.
Tsatsaragkou, K., Gounaropoulos, G., Mandala, I., 2014a. Development of gluten free bread containing carob flour and resistant starch. Lwt-Food Science and Technology 58, 124-129.
Tsatsaragkou, K., Yiannopoulos, S., Kontogiorgi, A., Poulli, E., Krokida, M., Mandala, I., 2014b. Effect of carob flour addition on the rheological properties of gluten-free breads. Food and Bioprocess Technology 7, 868-876.
Turbin-Orger, A., Boller, E., Chaunier, L., Chiron, H., Della Valle, G., Reguerre, A.L., 2012. Kinetics of bubble growth in wheat flour dough during proofing studied by computed X-ray micro-tomography. Journal of Cereal Science 56, 676-683.
Upadhyay, R., Ghosal, D., Mehra, A., 2012. Characterization of bread dough: Rheological properties and microstructure. Journal of Food Engineering 109, 104-113.
Vallons, K.J.R., Ryan, L.A.M., Koehler, P., Arendt, E.K., 2010. High pressure-treated sorghum flour as a functional ingredient in the production of sorghum bread. European Food Research and Technology 231, 711-717.
van Duynhoven, J., Voda, A., Witek, M., Van As, H., 2010. Time-domain NMR applied to food products. Annual Reports on Nmr Spectroscopy, Vol 69 69, 145-197.
van Riemsdijk, L.E., Peigrom, P.J.M., van der Goot, A.J., Boom, R.M., Hamer, R.J., 2011a. A novel method to prepare gluten-free dough using a meso-structured whey protein particle system. Journal of Cereal Science 53, 133-138.
van Riemsdijk, L.E., van der Goot, A.J., Hamer, R.J., 2011b. The use of whey protein particles in gluten-free bread production, the effect of particle stability. Food Hydrocolloids 25, 1744-1750.
Velazquez, N., Sanchez, H., Osella, C., Santiago, L.G., 2012. Using white sorghum flour for gluten-free breadmaking. International Journal of Food Sciences and Nutrition 63, 491-497.
Verdu, S., Ivorra, E., Sanchez, A.J., Barat, J.M., Grau, R., 2015. Relationship between fermentation behavior, measured with a 3D vision Structured Light technique, and the internal structure of bread. Journal of Food Engineering 146, 227-233.
Wang, X., Choi, S.G., Kerr, W.L., 2004. Water dynamics in white bread and starch gels as affected by water and gluten content. Lebensmittel-Wissenschaft Und-Technologie-Food Science and Technology 37, 377-384.

Wilderjans, E., Luyts, A., Van Haesendonck, I., Brijs, K., Courtin, C.M., Delcour, J.A., 2013. A H-1 nucear magnetic resonance study of the changes occurring during pound cake storage. Magnetic Resonance in Food Science: Food for Thought, 72-80.

Witczak, M., Korus, J., Ziobro, R., Juszczak, L., 2010. The effects of maltodextrins on gluten-free dough and quality of bread. Journal of Food Engineering 96, 258-265.

Witczak, M., Juszczak, L., Ziobro, R., Korus, J., 2012. Influence of modified starches on properties of gluten-free dough and bread. Part I: Rheological and thermal properties of gluten-free dough. Food Hydrocolloids 28, 353-360.

Wolter, A., Hager, A.S., Zannini, E., Arendt, E.K., 2013. In vitro starch digestibility and predicted glycaemic indexes of buckwheat, oat, quinoa, sorghum, teff and commercial gluten-free bread. Journal of Cereal Science 58, 431-436.

Wolter, A., Hager, A.S., Zannini, E., Arendt, E.K., 2014a. Influence of sourdough on in vitro starch digestibility and predicted glycemic indices of gluten-free breads. Food & Function 5, 564-572.

Wolter, A., Hager, A.S., Zannini, E., Czerny, M., Arendt, E.K., 2014b. Influence of dextran-producing Weissella cibaria on baking properties and sensory profile of gluten-free and wheat breads. International Journal of Food Microbiology 172, 83-91.

Wolter, A., Hager, A.S., Zannini, E., Czerny, M., Arendt, E.K., 2014c. Impact of sourdough fermented with Lactobacillus plantarum FST 1.7 on baking and sensory properties of gluten-free breads. European Food Research and Technology 239, 1-12.

Wolter, A., Hager, A.S., Zannini, E., Galle, S., Gaenzle, M.G., Waters, D.M., Arendt, E.K., 2014d. Evaluation of exopolysaccharide producing Weissella cibaria MG1 strain for the production of sourdough from various flours. Food Microbiology 37, 44-50.

Wronkowska, M., Zielinska, D., Szawara-Nowak, D., Troszynska, A., Soral-Smietana, M., 2010. Antioxidative and reducing capacity, macroelements content and sensorial properties of buckwheat-enhanced gluten-free bread. International Journal of Food Science and Technology 45, 1993-2000.

Wronkowska, M., Haros, M., Soral-Smietana, M., 2013. Effect of starch substitution by buckwheat flour on gluten-free bread quality. Food and Bioprocess Technology 6, 1820-1827.

Yano, H., 2010. Improvements in the bread-making quality of gluten-free rice batter by glutathione. Journal of Agricultural and Food Chemistry 58, 7949-7954.

Yano, H., 2012. Comparison of oxidized and reduced glutathione in the bread-making qualities of rice batter. Journal of Food Science 77, C182-C188.

Yano, H., Kaji, N., Tokuriki, M., 2013. Further studies on the protein chemistry and property of glutathione-added rice bread: evidence of glutathionylation of batter protein as well as crumb structure/sensory evaluation. Jarq-Japan Agricultural Research Quarterly 47, 417-421.

Zannini, E., Jones, J.M., Renzetti, S., Arendt, E.K., 2012. Functional replacements for gluten. Annual Review of Food Science and Technology, Vol 3 3, 227-245.

Ziobro, R., Korus, J., Witczak, M., Juszczak, L., 2012. Influence of modified starches on properties of gluten-free dough and bread. Part II: Quality and staling of gluten-free bread. Food Hydrocolloids 29, 68-74.

Ziobro, R., Korus, J., Juszczak, L., Witczak, T., 2013a. Influence of inulin on physical characteristics and staling rate of gluten-free bread. Journal of Food Engineering 116, 21-27.

Ziobro, R., Witczak, T., Juszczak, L., Korus, J., 2013b. Supplementation of gluten-free bread with non-gluten proteins. Effect on dough rheological properties and bread characteristic. Food Hydrocolloids 32, 213-220.

Tables

Table 1: Gluten-free bread recipes based on rice flour and analyses on the batter/dough and bread.

Additive(s)	Variable additive or flour treatment	H_2O	Analyses of batter/dough						Analyses of bread								Ref
			Rheology														
			Small deformation	Large deformation	Rheofermento-meter	Properties during heating	SDS-PAGE	**Other**	Texture analysis	Storage (days)	Image analysis	Sensory analysis	DSC	Crumb/crust color	SEM	Other	
HPMC	rice varieties	89-144%		x				DSC	x	1							1
HPMC	rice grain length; flour particle size	80%/110%			x			SEM	x								2
HPMC	mixing time, speed dough hook/ flat beater/ wire whip	80/110%			x				x								3
HPMC	flour particle size	70-110%							x							*in vitro* starch digestibility, GI	4
HPMC	extruded rice flour		x		x	RVA		SEM	x	3							5
HPMC	chia seed	100%			x	RVA			x			x		x			6
HPMC	SPI, calcium caseinate, egg albumin, pea protein isolate acetic acid, lactic acid	80%	x			RVA											7
HPMC	acetic acid, lactic acid, citric acid, NaH_2PO_4	110%	x					pH			x	x					8
HPMC	-	110%							x	8			x				9
xanthan gum HPMC	-	120-130%							x		x						10
HPMC, CMC, emulsifier (sorbitan fatty acid monostearate), hemicellulase, EWP	fractions of rice flour	90%				RVA		batter color	x			x		x	x		11

improver (corn starch, SSL, ascorbic acid, α-amylase); xanthan gum	TGase, casein, albumin	115%		x					x								12
-	HPMC (semi-firm / weak gel forming) barley β-glucan	70%	x	x		RVA											13
-	HPMC, barley β-glucan	70-110%							x	9		x		x			14
-	HPMC, Psyllium fiber	90-110%	x						x								15
EWP, WPC, DATEM, LBG, α-amylase	carob flour	70-150%							x		x					chemical analysis, crumb porosity	16
EWP, WPC, DATEM, LBG, α-amylase	carob flour	70-150%	x														17
EWP, WPC, DATEM, LBG, α-amylase	carob flour, resistant starch	80-140%							x		x					crumb porosity	18
-	gums (xanthan/ guar/ LBG/ pectin/ HPMC) Emulsifiers (DATEM/ Purawave)	150%	x						x			x					19
-	gums (xanthan, guar, LBG, agar, MC, CMC, HPMC), emulsifier (DATEM)	143%							x							X-ray µCT analysis	20
ascorbic acid	-	500FU		x					x								21
-	bovine plasma protein + sucrose/inulin	60%							x		x	x		x	x		22
-	peptidase	77%					x	microscopy	x						x		23
-	peptidase, thermoase	77%					x		x	3				x	x		24
TGase	WPC, sodium caseinate, SPI	110%				RVA			x		x	x					25
-	pregelatinised cassava starch, TGase	80%	x			RVA		DSC	x		x			x			26
-	buckwheat flour (husked/unhusked)	180-190%	x			ML			x			x					27
-	-	120%			x				x	5	x	x			x	water activity	28
-	-	95%							x	5			x			^{1}H-NMR	29
-	glutathione	100%				RVA	x	SEM							x		30
-	glutathione	100%				RVA	x					x			x	headspace gas analysis	31
-	glutathione	100%					x					x				headspace gas analysis	32

References: 1. Han et al. (2012), 2. De la Hera et al. (2013a), 3. Gomez et al. (2013), 4. De la Hera et al. (2014), 5. Martinez et al. (2014b), 6. Steffolani et al. (2014), 7. Ronda et al. (2014), 8. Blanco et al. (2011), 9. Ronda and Roos (2011), 10. Hager and Arendt (2013), 11. Park et al. (2014), 12. Storck et al. (2013), 13. Ronda et al. (2013), 14. Perez-Quirce et al. (2014), 15. Mancebo et al. (2015), 16. Tsatsaragkou et al. (2012), 17. Tsatsaragkou et al. (2014b), 18. Tsatsaragkou et al. (2014a), 19. Demirkesen et al. (2010b), 20. Demirkesen et al. (2014), 21. Buresova et al.

(2014), 22. Furlan et al. (2015), 23. Hatta et al. (2015), 24. Kawamura-Konishi et al. (2013), 25. Shin et al. (2010), 26. Pongjaruvat et al. (2014), 27. Torbica et al. (2010), 28. Hager et al. (2012), 29. Hager et al. (2014), 30. Yano (2010), 31. Yano (2012), 32. Yano et al. (2013)

Abbreviations: TPA, texture profile analysis; DSC, differential scanning calorimetry; SEM, scanning electron microscopy; HPMC, hydroxypropyl methylcellulose; GI, glycemic index; RVA, rapid visco-analyzer; (C)MC, (carboxy)methylcellulose; EWP, egg white powder; SSL, sodium stearoyl lactylate; TGase, transglutaminase; WPC, whey protein concentrate; DATEM, diacetyl tartaric acid ester of mono- and diglycerides; LBG, locust bean gum; SPI, soy protein isolate; ML, Mixolab; NMR, nuclear magnetic resonance.

964 Table 2: Gluten-free bread recipes based on different types of starch and analyses on batter/dough and bread.

Standard recipe		Variable additive	H_2O	Analyses of batter/dough						Analyses of bread							Ref
				Rheology													
Starch source(s)	Additive(s)			Small deformation	Large deformation	Rheofermentometer	Properties during heating	DSC	Other	Texture analysis	Storage (days)	Image analysis	Sensory analysis	DSC	Crumb/crust color	Other	
corn starch, potato starch	guar gum, pectin	maltodextrins	103%	x			RVA			x	2			x			33
corn starch, potato starch	guar gum, pectin	bean starch	100%							x	10			x		starch, protein content RVA	34
corn starch, potato starch	guar gum, pectin	defatted blackcurrant/strawberry seeds	105-118%	x	x					x	1		x		x	crumb porosity dietary fiber, polyphenol content	35
corn starch, potato starch	guar gum, pectin	ADA HDP HACS	103%	x			RVA	x		x	2	x		x			*36 batter* 37 *bread*
corn starch, potato starch	guar gum, pectin	inulin (differing in degree of polymerisation)	99-107%							x	3	x		x			38 *batter* 39 *bread*
corn starch, potato starch	guar gum, pectin	albumin lupine protein soy protein concentrate collagen pea protein isolate	105% 114% 148% 123% 128%	x						x	2	x	x	x	x		40
corn starch, potato starch	pectin	calcium caseinate, calcium citrate	97%							x			x		x		41
corn starch, potato starch	inulin, pectin	calcium citrate, calcium lactate, calcium carbonate, calcium chloride	106%				ML			x	1	x	x		x	Ca determination	42
corn starch, potato starch	pectin	buckwheat flour	80%					x		x	3	x			x		43
corn starch, potato starch	pectin, calcium citrate	calcium caseinate, sodium caseinate, WP isolate, hydrolyzed WP	105%				ML			x					x	water activity	44
corn starch	zein, HPMC	defatted zein	94%						microscopy							volume	45

corn starch	-	carob germ flour HPMC	65-84%							x							46
corn starch	xanthan gum, emulsifiers	chickpea flour carob germ flour pea protein isolate soy flour	103%	x		x				x	5		x		x	CLSM, microbiological analysis	47
corn starch, rice extrudate	HPMC, guar gum	extruded flours: buckwheat/potato flakes/corn protein source: SPI/EWP/sodium caseinate TGase	125%							x						protein digestibility	48
corn starch corn starch, tapioca starch, potato starch, rice flour	*Psyllium* fiber, guar gum, maltodextrins	buckwheat, HPMC buckwheat, HPMC	100% 83%			x				x	3	x			x	water activity	49
corn starch	baking powder, xanthan gum, emulsifier	tigernut flour, chickpea flour	108%	x		x				x	4	x			x		50
wheat starch	-	WP (aggregates/cold set gel/particles)		x	x												51
wheat starch	-	WP particles	100%	x	x				CLSM			x					52
wheat starch	-	yam flour	75%		x										x		53
rice starch	-	WP isolate/ β-glucan/ HPMC	87%							x		x	x		x		54

965 **References:** 33. Witczak et al. (2010), 34. Krupa et al. (2010), 35. Korus et al. (2012), 36. Witczak et al. (2012), 37. Ziobro et al. (2012), 38. Juszczak et al. (2012), 39. Ziobro et al. (2013a), 40.
966 Ziobro et al. (2013b), 41. Krupa-Kozak et al. (2011a), 42. Krupa-Kozak et al. (2012), 43. Wronkowska et al. (2013), 44. Krupa-Kozak et al. (2013), 45. Schober et al. (2010), 46. Smith et al. (2012),
967 47. Minarro et al. (2012), 48. Smerdel et al. (2012), 49. Mariotti et al. (2013), 50. Aguilar et al. (2015), 51. Van Riemsdijk et al. (2011a), 52. Van Riemsdijk et al. (2011b), 53. Seguchi et al. (2012),
968 54. Kittisuban et al. (2014)

969 **Abbreviations:** DSC, differential scanning calorimetry; TPA, texture profile analysis; RVA, rapid visco-analyzer; ADA, acetylated distarch adipate; HDP, hydroxypropyl distarch phosphate; HACS,
970 high amylose corn starch; ML, Mixolab; HPMC, hydroxypropyl methylcellulose; CLSM, confocal laser scanning microscopy; SPI, soy protein isolate; EWP, egg white powder; TGase,
971 transglutaminase; WP, whey protein.

972 Table 3: Gluten-free bread recipes based on alternative flours including gluten-free cereal flours (except rice), pseudocereals, tubers, legume

973 flours and nuts and analyses on the batter/dough and bread.

Standard recipe				**Analyses of batter/dough**							**Analyses of bread**								
				Rheology															
Starch source(s)	**Additive(s)**	**Variable additive or flour treatment**	**H_2O**	Small deformation	Large deformation	Rheofermentometer	Properties during heating	DSC	**SEM**	**Other**	Texture analysis	Storage (days)	Image analysis	Sensory analysis	DSC	Crumb/crust color	SEM	Other	**Ref**
oat flour	-	glucose oxidase laccase peptidase	89%	x		x	RVA			biochemical analyses	x							capillary electrophoresis, CLSM	55
oat flour	-	high pressure treatment	95%	x					x	bright field microscopy	x	5				x			56
wholegrain oat flour	-	different oat varieties peptidase	120%	x			RVA				x	3				x			57
oat flour	HPMC	-	75-120%				RVA				x	3		x		x			58
oat flour, potato flour	-	xylanase, laccase, tyrosinase	89%		x						x	2							59
oat meal	-	oat β-glucan	farinograph		x					gas retention									60
corn flour, rice flour	soy flour	-	110-218%		x		RVA	x			x	3				x			61
corn flour, rice flour	soy flour	xanthan gum; gelatine; carrageenan; alginate; CMC	158%		x						x	3	x			x			62
corn flour, rice flour	soy flour	CMC/xanthan gum partial baking	150%								x	3	x		x				63
corn flour	HPMC	flour particle size	80%/ 110%	x		x	RVA			flour color	x								64
buckwheat flour rice flour white teff flour corn flour quinoa flour sorghum flour oat flour	-	-	85% 120% 95% 90% 95% 95% 95%			x					x	5	x	x			x	water activity microbial shelf-life	65
buckwheat flour teff flour rice flour	xanthan gum HPMC	-	85-95% 95-105% 120-130%								x		x						66

corn flour			90-100%																
oat flour rice flour	-	-	95%								x	5			x			^{1}H-NMR	67
amaranth flour chickpea flour millet flour corn flour buckwheat flour quinoa flour	ascorbic acid	-	farinograph		x						x								68
rice flour, buckwheat flour commercial mix	-	xanthan gum/propylene glycol alginate	80-100%	x					x		x								69
rice flour, buckwheat flour	-	microbial homoexopolysaccharides HPMC	100%							water holding capacity	x	7	x						70
buckwheat flour	-	TGase, (wheat gluten)		x			ML			SDS-PAGE, CLSM, free amino group quantification	-								71
chestnut flour, rice flour	-	different ratios gums (xanthan-guar/xanthan-LBG)/emulsifier (DATEM)	150-210%	x							x			x		x			72
chestnut flour, rice flour	DATEM, guar gum, xanthan gum	different ratios rice/chestnut flour conventional/ IR microwave oven	153-203%								x					x			73
tigernut flour, rice flour	DATEM, guar gum, xanthan gum	different ratios rice/tigernut flour conventional/ IR microwave oven	150-200%					x			x				x	x			74
chestnut flour, rice flour	-	DATEM, guar gum, xanthan gum conventional/ IR microwave oven	150-186%										x				x		75
chestnut flour, rice flour	-	DATEM, guar gum, xanthan gum conventional/ IR microwave oven	150-186%								x	4			x			X-ray analysis, FT-IR analysis	76
chestnut flour	-	NaCl, sucrose, chestnut starch		x			ML												77
chestnut flour, chia flour	-	guar gum, HPMC, tragacanth gum		x			ML												78
chestnut flour	-	chia flour, HPMC, guar gum		x			ML												79
sorghum flour	-	high pressure treatment	110%	x							x	3							80
sorghum flour	EWP	cassava/ corn/ rice/ potato starch	100%		x						x	4							81
soy flour	-	raw/germinated/steamed/roasted soy flour/ HPMC	100-140%							pH, volume changes	x		x	x					82

cassava flour	-	EWP	100-120%				RVA				x			x					83

References: 55. Renzetti et al. (2010), 56. Huttner et al. (2010c), 57. Huttner et al. (2010a), 58. Kim and Yokoyama (2011), 59. Flander et al. (2011), 60. Londono et al. (2015), 61. Sciarini et al. (2010b), 62. Sciarini et al. (2010a), 63. Sciarini et al. (2012a), 64. De la Hera et al. (2013b), 65. Hager et al. (2012), 66. Hager and Arendt (2013), 67. Hager et al. (2014), 68. Buresova et al. (2014), 69. Peressini et al. (2011), 70. Ruhmkorf et al. (2012), 71. Han et al. (2013), 72. Demirkesen et al. (2010a), 73. Demirkesen et al. (2011), 74. Demirkesen et al. (2013a), 75. Demirkesen et al. (2013b), 76. Demirkesen et al. (2014), 77. Moreira et al. (2011), 78. Moreira et al. (2013), 79. Moreira et al. (2014), 80. Vallons et al. (2010), 81. Onyango et al. (2011b), 82. Shin et al. (2013), 83. Pasqualone et al. (2010)

Abbreviations: DSC, differential scanning calorimetry; SEM, scanning electron microscopy; TPA, texture profile analysis; RVA, rapid visco-analyzer; CLSM, confocal laser scanning microscopy; HPMC, hydroxypropyl methylcellulose; CMC, carboxymethylcellulose; ^{1}H-NMR, proton nuclear magnetic resonance; TGase, transglutaminase; ML, Mixolab; LBG, locust bean gum; DATEM, diacetyl tartaric acid ester of mono- and diglycerides; IR, infrared; GI, glycemic index; EWP, egg white powder.

Table 4: Gluten-free bread recipes based on a combination of flour(s) and starch(es) and analyses on the batter/dough and bread.

Standard recipe		Variable additive or flour treatment	H_2O	Analyses of batter/dough							Analyses of bread								Ref
				Rheology															
Starch source(s)	Additive(s)			Small deformation	Large deformation	Rheofermentometer	Properties during heating	DSC	CLSM	Other	Texture analysis	Storage (days)	Image analysis	Sensory analysis	CLSM	Crumb/crust color	SEM	Other	
rice flour, cassava starch, corn starch	eggs, guar gum, CMC, soybean extract powder, emulsifier	-	-								x			x					84
rice flour, cassava starch	-	HPMC, xanthan	72%	x				x		TGA	x								85
rice flour, cassava starch	HPMC	SPI, EWP	optimal hydration	x				x		TGA	x			x					86
rice flour, cassava starch, soy flour	-	emulsifiers (DATEM, SSL) enzymes (glucose oxidase, α-amylase) hydrocolloids (xanthan gum, CMC, carrageenan, alginate)	65% 65% 75%	x	x			x		protein extraction	x	3d	x						87
rice flour,cassava starch	HPMC	amylopectin chain length	105%								x	3		x					88
rice flour, cassava starch	EWP, HPMC, SSL	apple pomace	115-150%	x							x	1	x			x			89
rice flour, potato starch, cassava starch, sour cassava flour	egg	sugar/sucralose/fructose/ stevia/FOS/inulin	85%								x			x		x			90
rice flour, potato starch, cassava starch, sour cassava flour	egg	sucralose/fructose/stevia/FOS/ inulin	85%											x					91
rice flour, potato starch	xanthan gum	amaranth/quinoa/buckwheat flour	87%				RVA				x	5	x	x	x	x	x		92
rice flour, potato starch	WPI, xanthan, HPMC	β-glucan, inulin	59-132%	x							x	5			x	x		β-glucan quantification	93
rice flour, potato starch	xanthan gum, CMC	fructans	85%								x	2		x		x		dietary fiber, glycemic response	94
rice flour, potato starch	MC	orange pomace	85-94,6%	x	x		ML + RVA		x	cryo-SEM				x	x		x		95
rice flour, potato starch	MC	orange pomace	85-100%								x	1	x					fiber analysis	96

rice flour, corn starch, potato starch	milk powder/ EWP/SPI/xanthan/ HPMC/ pectin	different blends	56-110%				ML				x			x		x		water activity chemical composition	97
corn starch, rice flour	-	HPMC	70-95%								x	6		x			x		98
corn starch, rice flour	-	HPMC, xanthan, k-carrageenan, guar gum	70-105%	x				x			x	2		x		x	x		99
corn starch, rice flour, soy flour, buckwheat flour	albumen, xanthan gum, emulsifiers (esters of MAG and DAG)	unicellular protein	90-110%								x			x	x	x		microbiological analysis	100
rice flour, corn starch, corn flour quinoa flour, corn starch	HPMC HPMC	enzymes (α-amylase/ amyloglucosidase) sucrose whole grain/white flour	80%								x			x					101
rice flour, corn flour, corn starch	HPMC	quinoa flour	80%	x		x					x		x	x					102
corn starch, rice flour	HPMC	fibers (oat, bamboo, potato, pea), polydextrose	80%	x		x				SEM	x	8	x			x			103
corn flour, rice flour, rice starch, rice protein	HPMC, LBG, guar gum, maltogenic amylase	psyllium fiber, sugar beet fiber	(farinograph)			x				image analysis, farinograph	x	3	x			x			104
rice flour, corn flour, buckwheat flour, corn starch, potato starch	inulin, guar gum	freezing of dough	86%	x						temperature recording	x		x						105
rice flour, GF wheat starch	albumen, DATEM, distilled MAG, HPMC	rice bran	100% (flour basis)								x	9	x	x		x		protein, dietary fiber content	106
rice flour, GF wheat starch	albumen, DATEM, distilled MAG, HPMC	green plantain flour	120-160%								x		x			x		resistant starch content	107
corn starch, potato starch, rice flour, amaranth flour	LBG, α-amylase, DATEM	albumen	60-80%								x		x	x		x			108
corn flour, corn starch, potato starch, amaranth flour	HPMC, guar gum, pectin, gluconic acid lactone, LBG	freezing of dough	81%	x	x			x											109
corn starch	zein	HPMC, high β-glucan oat bran	65-80%	x	x				x				x						110
cassava starch, corn flour	-	soybean flour, whole egg	50-58%								x			x					111
corn starch, sorghum flour	HPMC	corn/sorghum ratio	90-110		x									x					112
corn flour, corn starch, potato starch	xanthan gum	SPI, WPI, TGase	-								x	2		x				crumb porosity	113

soy flour, corn starch, amaranth flour	guar gum, lecithin, albumen, enzymes, DATEM	iron sources	80%								x			x		x		crust texture	114
soy flour, corn starch, amaranth flour	guar gum, lecithin, albumen, enzymes, DATEM	iron sources	80%								x			x		x		crust texture	115
sorghum flour, pregelatinised cassava starch	EWP	TGase	102%	x							x	4							116
sorghum flour, native/pregelatinized cassava starch	EWP	α-amylase	80-100%	x							x								117
sorghum flour, native/pregelatinized cassava starch	EWP	different flour/starch blends	100%	x							x	1	x						118
sorghum flour, potato starch	HPMC	different extraction rate of sorghum flour	104-135%		x						x		x						119
commercial mix (wheat starch)	guar gum, HPMC	DATEM, time-temperature-pressure treated oat flour	83-90%								x	3						DSC, ^{1}H- NMR	120

References: 84. Schamne et al. (2010), 85. Crockett et al. (2011a), 86. Crockett et al. (2011b), 87. Sciarini et al. (2012b), 88. Aoki et al. (2015), 89. Parra et al. (2015), 90. De Morais et al. (2013), 91. De Morais et al. (2014), 92. Alvarez-Jubete et al. (2010), 93. Hager et al. (2011), 94. Capriles and Areas (2013), 95. O'Shea et al. (2013), 96. O'Shea et al. (2015), 97. Matos and Rosell (2013), 98. Sabanis and Tzia (2011a), 99. Sabanis and Tzia (2011b), 100. Minarro et al. (2010), 101. Elgeti et al. (2014), 102. Foste et al. (2014), 103. Martinez et al. (2014a), 104. Cappa et al. (2013), 105. Mezaize et al. (2010), 106. Phimolsiripol et al. (2012), 107. Sarawong et al. (2014), 108. Schoenlechner et al. (2010), 109. Leray et al. (2010), 110. Andersson et al. (2011), 111. Milde et al. (2012), 112. Velazquez et al. (2012), 113. Dluzewska et al. (2015), 114. Kiskini et al. (2010), 115. Kiskini et al. (2012), 116. Onyango et al. (2010b), 117. Onyango et al. (2010a), 118. Onyango et al. (2011a), 119. Trappey et al. (2015), 120. Purhagen et al. (2012)

Abbreviations: TPA, texture profile analysis; SEM, scanning electron microscopy; (C)MC, (carboxy)methylcellulose; HPMC, hydroxypropyl methylcellulose; TGA, thermogravimetric analysis; SPI, soy protein isolate; EWP, egg white powder; DATEM, diacetyl tartaric acid ester of mono- and diglycerides; SSL, sodium stearoyl lactylate; FOS, fructooligosaccharides; RVA, rapid visco-analyzer; WPI, whey protein isolate; ML, Mixolab; MAG, monoacylglycerol; DAG, diacylglycerol; LBG, locust bean gum; TGase, transglutaminase; ^{1}H-NMR, proton nuclear magnetic resonance.

Table 5: Gluten-free bread recipes using sourdough and analyses on the batter/dough and bread.

Standard recipe			Analyses of batter/dough							Analyses of bread							
			Rheology														
Starch source(s)	Additive(s)	H_2O	Small deformation	Large deformation	Rheofermentometer	Properties during heating	pH	Capillary gel electrophoresis	other	Texture analysis	Storage (days)	Image analysis	Sensory analysis	pH	Crumb/crust color	Other	Ref
oat flour	-	120%	x				x	x	identification of LAB	x	5				x		121
buckwheat flour quinoa flour sorghum flour teff flour	-	85% 95% 95% 95%	x							x	5	x	x			SEM	122
buckwheat flour bat flour quinoa flour sorghum flour teff flour	-	85% 95% 95% 95% 95%	x				x	x		x	5	x	x			microbial shelf-life	123
buckwheat flour	-	95%	x		x		x	x		x	5			x			124
buckwheat flour / brown rice flour	reducing/ oxidizing strain	100%	x				x	x		x		x					125
rice flour	-	132%		x		RVA			SDS-PAGE							volume	126
rice flour, extruded corn flour, corn starch, potato starch, buckwheat flour	inulin, guar gum, Na caseinate	110%					x			x	3			x		lactic & acetic acid concentration chemical analysis pasting characteristics GI *in vivo*	127
corn flour, rice flour, buckwheat flour	freeze-drying of sourdough	90-102%								x	3	x	x	x			128
corn flour	-		x	x					DSC, CLSM	x		x				CLSM	129
sorghum flour	-	90%	x		x		x			x	5			x			130
fonio/sorghum flour	-	75%				ML			starch analysis							crumb texture (visually)	131
quinoa flour	-	95%							analysis of sourdough metabolites & antifungal compounds	x	5	x				microbial shelf-life	132

References: 121. Huttner et al. (2010b), 122. Wolter et al. (2014b), 123. Wolter et al. (2014c), 124. Moroni et al. (2011), 125. Capuani et al. (2014), 126. Hamada et al. (2013), 127. Novotni et al. (2012), 128. Rozylo et al. (2015), 129. Falade et al. (2014), 130. Galle et al. (2012), 131. Edema et al. (2013), 132. Axel et al. (2015)

Abbreviations: TPA, texture profile analysis; LAB, lactic acid bacteria; SEM, scanning electron microscopy; RVA, rapid visco-analyzer; GI, glycemic index; DSC, differential scanning calorimetry; CLSM, confocal laser scanning microscopy; ML, Mixolab.

Figure captions

Figure 1

Literature search on the topic gluten-free bread making. Source: Web of Science, all databases, leaving out research areas in the medical field, up until April 8th, 2015. The number of publications of 2015 (shown in grey) is estimated based on the number of publications during the first three months of that year.

Figures

Figure 1